UNITED STATES DEPARTMENT OF AGRICULTURE

SURVEY REPORT
FOUNTAIN RIVER WATERSHED
COLORADO
1950

UNITED STATES DEPARTMENT OF AGRICULTURE
PRODUCTION AND MARKETING ADMINISTRATION
Colorado State Office
948 Broadway
Denver 2, Colorado

C O P Y

In reply refer to:
5a

August 9, 1950

Mr. Reed W. Bailey, Director
Intermountain Forest and
Range Experiment Station
Forest Service Building
Ogden, Utah

Re: RIFC-INT, Fountain River Survey Report

Dear Mr. Bailey:

Reference is made to your letter of July 5 enclosing a revised draft of the flood control survey report and appendix material for the Fountain River watershed.

We have reviewed this material and have noted the corrections of which you advised us under date of July 21. It appears that an excellent job has been done in analyzing the various aspects of the problems involved and in presenting them in an understandable manner. The recommendations with respect to measures of land treatment appear to be well chosen and will satisfactorily supplement those being carried out under going programs.

We would like to make one comment concerning the average cost per mile for terracing crop land. It is realized that all cost estimates were based on 1947 prices, however, the development of new types of terracing equipment since then has greatly reduced the cost of terracing. If it would not unduly delay the completion of the report it might be advisable to make a further study of present costs and possibly make a downward adjustment in this particular estimate.

Thank you for affording us the opportunity of reviewing the report.

Sincerely yours,

Warren A. Myers
Administrative Assistant

~~UNITED~~ ~~STATES~~ DEPARTMENT OF AGRICULTURE

SURVEY REPORT

ON PROGRAM OF RUNOFF AND WATER FLOW RETARDATION AND

SOIL EROSION PREVENTION FOR FLOOD CONTROL PURPOSES

FOUNTAIN RIVER WATERSHED, COLORADO

In compliance with
the Flood Control Act of June 22, 1936, 49 Stat. 1570, as supplemented
by the Act of June 28, 1938, 52 Stat. 1215

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SUMMARY

A survey of the Fountain River watershed has been made to determine the nature and extent of its flood and erosion problems and to outline a program for ameliorating damages caused by floods and sediment and to reduce the threat of loss of life. Fountain River drains an area of 927 square miles and joins the Arkansas River within the city of Pueblo, Colorado. Excessive surface runoff and accelerated erosion from the upland areas have produced floods and sediments causing excessive damage to bottom land values within the watershed and in the Arkansas River valley below the confluence of the two rivers. A number of lives have been lost during flash floods. Monetary damages from such floods are estimated at $300,500 annually. A watershed restoration and management program is recommended to reduce these damages and to provide increased protection to the residents of the watershed.

The recommended program contemplates the adoption of interdependent measures on cultivated, range, and forest areas designed to reduce and retard surface runoff, stabilize the soil mantle, and check accelerated erosion resulting in the reduction of flood and sediment damages. The estimated cost of installing the program, including maintenance during the installation period is $4,020,000. Of this amount it is recommended that the Federal Government contribute about $3,439,000, and non-Federal interests about $581,000. After installation, annual maintenance will cost the Federal Government about $4,900 and non-Federal interests approximately $37,700. These costs are based on the assumption that the Department of

Agriculture's current program within the watershed, a portion of which contributes to flood and sediment control, will continue at about the present rate.

It is anticipated that the recommended program will be installed on non-Federal lands under cooperative agreements with local public agencies and governments acceptable to the Secretary of Agriculture.

The over-all ratio of benefits to costs is 1.70:1.

INTRODUCTION

Authority

This report has been prepared in compliance with Section 6 of the Flood Control Act of June 22, 1936, (49 Stat, 1570) ~~Public No. 738, 74th Congress,~~ as amended by Section 5 of the Flood Control Act of August 28, 1937, (50 Stat. 876) ~~Public No. 406, 75th Congress~~ which is quoted in part as follows: "The Secretary of Agriculture is authorized and directed to cause... surveys for runoff and waterflow retardation and soil erosion prevention on the watersheds of ... Fountaine Qui Bouille (Fountain) River watershed, Colorado..."

DESCRIPTION OF THE WATERSHED

Location and Physiography

Fountain River, in east central Colorado, is a south-flowing stream draining an area of 927 square miles and emptying into the Arkansas River within the city of Pueblo (map 1). The basin is somewhat fan-shaped with a length of about 65 miles and maximum width of 25 miles.

The front range of the Southern Rocky Mountains rises rather abruptly from the plains in the northwestern portion of the watershed forming a great escarpment with elevations ranging up to 14,110 feet at Pikes Peak. In the mountainous portion of the watershed valleys are narrow, steep walled and straight, and divides are broad, rounded remnants of an old peneplain. A narrow band of foothills below the mountains grades into the plains portion of the watershed where streams flow in meandering courses in broad open valleys separated by long, low dividing ridges and elevations drop to 4,700 feet.

U. S. DEPARTMENT OF AGRICULTURE
FOREST SERVICE
INTERMOUNTAIN FOREST & RANGE EXPERIMENT STATION
OGDEN, UTAH
FLOOD CONTROL SURVEY
FOUNTAIN RIVER WATERSHED - COLORADO
GENERAL
SUBMITTED
DATE
APPROVED
DATE
COMPILED
TRACED B.F.T.
CHECKED
MAP NO.
APPENDIX NO.
KEY MAP
WYOMING
NEB
UTAH
COLORADO
NEW MEXICO
KANSAS
DENVER
FOUNTAIN RIVER WATERSHED
SCALE
MILES
N
PALMER LAKE
MONUMENT
HUSTED
WOODLAND PARK
GREEN MTN FALLS
CASCADE
MANITOU
COLORADO SPRINGS
EDGERTON
BEECH
FALCON
TEMPLETON GAP
BROADMOOR
PIKES PEAK
LAKE MORAINE
EL PASO CO
TELLER CO
TELLER COUNTY
EL PASO COUNTY
PIKE NATIONAL FOREST
MOUNTAINOUS AREA
NORTHERN PLAINS AREA
SOUTHERN PLAINS AREA
PETERSON FIELD
CAMP CARSON
FOUNTAIN
BUTTES
PINON
EL PASO COUNTY
PUEBLO COUNTY
PUEBLO
ARKANSAS RIVER
FOUNTAIN RIVER

Channel gradients vary from 25 feet per mile in the lower reaches of the main river to as much as 500 feet per mile in the mountains. Channels in the plains area are rectangular in shape with practically vertical sides and bottoms of loose sand or gravel. Mountain stream channels are somewhat V-shaped with banks frequently merely extensions of upland slopes.

Climate

Wide variations in climatic conditions result from the great differences in elevation and physiography. Average annual precipitation ranges from about 11 inches in the plains area to about 25 inches in the mountains with up to 85 percent of the precipitation at low elevations occurring as rainfall during the months of April through September. In the mountainous portion about one-third of the annual precipitation occurs in the form of show which provides the principal source of water for irrigation and domestic needs. Average annual temperatures range from about 52° F. in the plains area to about 36° F. in the mountains and temperature extremes of -27° F. and over 100° F. have been recorded. The growing season ranges from 100 to 160 days in the plains portion of the watershed but drops to less than 60 days in the higher mountains.

Flood-producing storms normally occur during the summer months and are most frequently of the convective or "thunderstorm" type. Such storms have produced as much as 2.3 inches of rainfall in an hour. Intensities of 4.4 inches per hour have been recorded for shorter periods. General summer storms, sometimes in combination with the convective type, have caused some of the worst floods due

to their widespread nature; however they are less frequent. As an example, 5.2 inches of rainfall in less than 7 hours have been recorded for such storms with much higher unofficial observations reported. General winter storms are normally of low intensity and rarely produce excessive flood peaks.

Geology, Soils, and Erosion

Surface formations of sedimentary rocks, limestones, sandstones, shales, and arkoses occupy about 64 percent of the watershed and characterize most of the plains and foothills. Granitic formations in the mountains comprise about 25 percent of the drainage with the remaining 12 percent of the watershed composed largely of valley alluvial deposits including glacial drift and terrace gravels.

The heavy-textured soils located largely within the southern plains area, have relatively low infiltration rates, are highly susceptible to erosion and are the most important contributors of sediment in the Fountain drainage. Light-textured soils derived from the Dawson Arkose formation are prevalent in the northeastern part of the watershed. These soils vary in erodibility from slight to moderate, have moderate infiltration rates but low water-holding capacity. The sandy alluvial soils of the valleys include the best cropland soils and are characterized by high infiltration rates, low runoff, and slight to moderate erodibility. The granitic soils of the mountains have high infiltration rates but due to their generally shallow depth produce runoff during times of heavy rainfall.

The most serious erosion conditions in the watershed are found in the southern plains area. On about one-third of this area sheet

and gully erosion have progressed until infiltration and productivity rates have been seriously reduced with a material increase in surface runoff and sediment production. About 7,200 acres in this area have been covered by depositional material and over 10,000 acres have been classed as destroyed for crop production. In the northern plains, erosion conditions are most serious in and adjacent to the stream channels, many of which have increased their width several fold in the past 35 years. About 5,300 acres are classed as destroyed due to gullying. The Black Forest area in this portion is characterized by shallow soils, excessive slopes, and inadequate litter. Here accelerated sheet erosion is prevalent. The mountainous area in general has been subjected to moderate sheet erosion accompanied by occasional gullies. A combination of overuse, fires, steep slopes, and a rather unstable soil mantle has resulted in soil deterioration throughout much of this area.

Plant Cover

The grassland type, with blue grama the most important species, extends over about 239,000 acres in the plains area. In the southern plains, annual grasses and weeds have replaced good perennial grasses on over 70,000 acres as a result of overuse especially during dry seasons. The conifer and timber types of the mountains and Black Forest region occur on almost one-fifth of the total watershed lands with ponderosa pine and Douglas-fir the most common species. Broadleaf trees, principally aspen, and browse species occupy about 76,000 acres in the foothills and mountains. Less important cover types occurring in limited areas are saltbush, barren, water surfaces, meadow, pinyon-juniper, and half shrub.

LAND AND WATER ECONOMY

Population and History of Development

The normal total population of the watershed is about 65,000, or 70 persons per square mile, including 56,000 in Colorado Springs and that portion of Pueblo within the drainage. Highly commercialized recreational developments and unusual scenic attractions more than double the population of Colorado Springs, Manitou Springs, and surrounding areas during the summer months. The farm population of about 1,400 persons, with a density of 1.5 persons per square mile, has been declining during recent years.

The development of the watershed began with an influx of miners following the discovery of gold in the Pikes Peak region in 1858. Agricultural enterprises which were first started to supply the miners grew rapidly as transportation outlets and markets developed. The first small tract of land was irrigated in 1860, and in 1861 and 1862 the first herds of cattle and sheep appeared in the valley. The livestock industry increased significantly during three specific periods, the first during the Civil War, the second between 1880 and 1885, and the third following World War I. These developments resulted in the grazing of many more cattle than the forage growth would support and severe depletion of the range occurred on many areas.

Rail transportation was provided in 1871 when the Denver and Rio Grande Western Railroad constructed a line to Colorado Springs.

The Pikes Peak Timber Reserve, created in 1892 became the Pike National Forest in 1907. Numerous additions, eliminations and consolidations have resulted in the present national forest area of

which 110,900 acres lie within the watershed. During the period 1850 to 1870 many acres of timberland were burned over but beginning with creation of the Timber Reserves organized fire control activities were inaugurated and as early as 1903 reforestation of the burned areas was started.

Land Ownership, Use, and Management

Private individuals and corporations own almost two-thirds of the land in the watershed. For the most part these lands are in the plains section. Federally owned lands amount to about 30 percent of the total and include 110,900 acres in the Pike National Forest and 60,600 acres in the Military Reservation of Camp Carson and Peterson Field south and east of Colorado Springs. Slightly more than 6 percent of the land is owned by municipalities, counties, and the State of Colorado.

Table 1 is a brief summary showing the major uses which watershed lands serve.

Of the 39,000 acres in cultivation about 44 percent is planted to corn, 17 percent to other row crops, 8 percent to small grains, 27 percent to feed crops, and the remaining area is fallow or idle. A high percentage of the irrigated land is located along the Fountain River between Colorado Springs and Pueblo where water is supplied by direct diversion and a few off-stream reservoirs. This valuable cultivated land is frequently subjected to extensive damage and destruction from bank cutting and lateral widening of the river channel. The dry-farm acreage is located adjacent to the irrigated fields and in scattered tracts throughout the watershed. Cropping practices vary greatly but in general comparatively little attention has been given to soil

Table 1. Major land uses, Fountain River watershed, Colorado, 1947

Major land use	Area	
	Acres	Percent
Cropland		
Irrigated	15,000	2.5
Dry-farm	24,053	4.1
Water source areas 1/		
National forest	72,339	12.2
Municipal and private	11,000	1.9
Range and woodland areas	400,537	67.5
Military establishments	60,610	10.2
Urban	9,696	1.6
Watershed total	593,235	100.0

1/ Areas used for municipal and private domestic water supply purposes.

conservation. Cultivation is often practiced on steep slopes where sheet erosion and gully development are progressing, contour planting is negligible, subsoils are exposed, and continued declines in yield and fertility are taking place on many of the farms. Establishment of a soil conservation demonstration project and organization of soil conservation districts together with the activities of the Agricultural Extension Service and the Agricultural Conservation Program have aided in establishing conservation measures on a limited number of farms.

About 83,000 acres have been set aside as a municipal and private water source area to assure a supply of domestic water for the local population. Some 72,000 acres are national forest lands with the remainder largely owned by the city of Colorado Springs. In this area all authorized grazing and timber cutting has been excluded. The national forest portion has been under management since 1892 and closed to grazing for more than 30 years. Exclusion of grazing, reforestation, fire prevention and suppression, and, for the municipal and privately owned lands, boundary fences and resident caretakers have protected these lands from all forms of use that might disturb natural cover conditions which are now excellent.

Camp Carson, a permanent army post of 57,730 acres, on the plains south of Colorado Springs, and Peterson Field, about 2,880 acres east of the same city, have been closed to all types of non-military use since acquisition by the Department of the Army in 1941-42. Prior to the closure, the estimated grazing capacity of this 60,600 acres was about 10,530 a.u.m. Some of the acreage is

devoted to administrative use but the major portion is used only for rifle ranges and miscellaneous maneuvers. The exclusion of livestock and other use restrictions have permitted the native cover to make excellent recovery. Both reservations now are good examples of vegetative recovery which may be expected elsewhere under improved treatment. For purposes of this report, no consideration is given to the forage now produced on them, as it cannot be determined if or when any of these lands will be re-opened to livestock.

The remaining watershed acreage, excluding urban areas, comprises 362,000 acres of non-Federal range and woodland-range. Many range operators, especially on small ranches, have not adopted the most progressive methods of range management. Such undesirable practices as yearlong grazing without rotation or adjustments to carrying capacity, and salting near water developments are common. In 1946, 19,500 head of livestock grazed these lands and demanded the equivalent of 110,300 a.u.m. of forage. In comparison, actual grazing capacity, including utilization of regrowth on meadow land after hay harvest, amounted to only 96,550 a.u.m. Thus overutilization amounting to 13,750 a.u.m. resulted even though livestock numbers were somewhat less than the previous 10-year average, and 1947 was in a favorable climatic cycle. A similar unbalanced situation has existed for many years.

There are 153,200 acres of timberland within the watershed. The total includes 98,800 acres on national forest, 5,200 on military establishments, 7,600 acres on municipal and private domestic water source areas and 41,600 acres on other privately owned lands. Almost three-fourths of the timberland is in conifers; one-fifth is in aspen; and less than 5 percent supports a pinyon-juniper type. Ponderosa pine and

Douglas-fir comprise almost 80 percent of the total estimated timber volume of 134,500,000 board feet. Of the total volume, about 86,000,000 board feet are located on the Pike National Forest, military establishments, and municipal and private domestic water source areas. The remaining volume is on private land largely outside the national forest boundary and includes timber on 15,700 acres in the Black Forest area in the northeastern portion of the watershed.

Privately owned timberlands, excluding those managed for domestic water supply purposes, are generally subjected to poor treatment and management. Most of them have been cut over repeatedly and grazed heavily with burning often resorted to in an effort to encourage early grass and weed growth for livestock use. This abusive treatment has left many of the stands in a poor condition from the standpoint of runoff retardation and erosion prevention. A farm forester has been working in the Black Forest area and as a result of his efforts improved forestry management practices have been installed on a limited number of farms and ranches. Unfortunately this project has been discontinued due to lack of funds.

Farm Features

There are about 355,300 acres of land in farms managed by 400 farm operators. Seventy percent of the operators, controlling 84 percent of the acreage, are owners or part owners. The remaining 30 percent are share-crop or cash tenants who usually obtain leases for one year with renewal privileges. More than one-third of the operators have been on the farms for 10 years or more and the current trend is toward longer tenure and outright ownership.

Of 396 farm units, 43 percent are livestock farms; 14 percent crop farms; and 43 percent part-time, miscellaneous, and rural non-farm units. Seasonal recreational and industrial employment results in considerable part-time farming and many urban business people live in the country in rural nonfarm homes. The large number of part-time, miscellaneous, and nonfarm units has a tendency to create rural land values which cannot be supported by normal farm operations.

The average size of farm units is about 900 acres. However, one-fourth of the farms contain 80 acres or less per farm. Livestock ranches are principally in the large size class with more than 30 units in excess of 1,900 acres each.

Based on 1945 U. S. Census data, the estimated value of farm property in the watershed is $18,530,000. For the same year the estimated value of all livestock and crops sold or used in farm households amounted to $5,687,000, one-half of which resulted from the sale of livestock products.

Water Supply

There are 10 cities and towns, including Colorado Springs, that are wholly or partially dependent on the watershed for water. Municipal systems largely supplied by perennial mountain streams provide water for domestic, industrial, and minor farm use. The majority of the farms depend upon wells, springs, or streams for stock and domestic water.

Stream pollution is not an important problem within the watershed since there is little waste from industrial plants and sewerage is handled adequately.

In 1947, 15,000 acres in the Fountain Valley were irrigated mostly by direct diversion. An additional 5,000 to 6,000 acres in the Arkansas valley were dependent on the Fountain River for water supply. In 1939 irrigation enterprises were capable of supplying 22,900 acres with water; however, only 14,500 acres were actually irrigated and irrigation was abandoned on 8,200 acres during the previous 10 years. The most important factors contributing to this decline are: increasing cost of maintaining diversion structures damaged by floods; change in character of stream flow from sustained summer discharges to extended periods of very low discharge; and inability to use flood waters because of high sediment content.

Recreation and Wildlife

The Colorado Springs-Pikes Peak area has been the center of a thriving tourist and recreational business for many years. The tourist industry alone contributes about 10 million dollars annually to the local income and private and public interests have invested large amounts in the development of natural points of interest.

On the Pike National Forest, summer home areas have been developed, camp grounds and picnic areas have been constructed, and scenic highways and horse and foot trails are provided and receive heavy use.

The Pikes Peak Game Refuge, about 170,000 acres in extent, includes a high percentage of the total wildlife in the watershed. On national forest lands, which make up about one-half the refuge area, there are about 1,500 mule deer and other forms of wildlife. There are a few deer in the Black Forest area and about 150 antelope in

the eastern plains portion of the watershed. No particular game problem exists within the watershed.

CURRENT AND PAST FLOOD CONTROL ACTIVITIES

No large-scale concerted efforts toward development of flood control measures have been undertaken over the basin as a whole.

Locally, steps toward flood control have been taken by Federal and state agencies, local communities, and individuals.

Municipalities

In cooperation with the Works Progress Administration, Colorado Springs has improved the Monument-Fountain channels through the city at a cost of $1,500,000. The major improvement was installation of grouted riprap channels with a designed capacity of 50,000 c.f.s., the estimated peak discharge of the May, 1935 flood.

In a similar manner, Pueblo spent $152,000 in 1937 straightening the channel of Fountain River and protecting a portion by hand-placed riprap.

Federal Agencies

House Document No. 186, 78th Congress, reports upon a survey of Fountain River by the Corps of Engineers. The construction of the Templeton Gap floodway for flood control at Colorado Springs was recommended. This has now been authorized and construction is under way.

Several Department of Agriculture agencies are engaged in conservation activities within the watershed and portions of their programs contribute to the alleviation of flood and sediment problems. It is estimated that annual expenditures of Federal funds by these

various agencies will amount to $62,000 during the installation period for measures deemed of primary importance to flood or sediment control, of which $4,400 will be expended on Federal lands and $57,600 on non-Federal lands through cooperative programs with land operators.

While several agencies are active within the watershed the extent to which each contributes to flood and sediment control varies with the nature and location of its work.

The Forest Service administers the Pike National Forest, 110,900 acres of which lies within the watershed, and in its management stresses the importance of watershed protection to reduce floods and erosion and to insure and improve the value of the watershed as an important water supply area. Measures currently being performed which contribute to flood control objectives consist of tree planting, fire protection, related range and timber improvement practices, and the improvement of drainage and prevention of erosion on mountain roads.

In 1934-35 the Forest Service constructed six flood control dams on Fountain Creek. Maintenance was the responsibility of local interests Although these dams were low in storage capacity, they effected some reduction in flash flows until their efficiency was impaired due to lack of maintenance. ~~The proposed program provides for repairing the largest of these dams. Other arrangements are being made to clean the remaining smaller dams thus restoring much of their original efficiency.~~

In addition to the above, under terms of the Norris-Doxey Act, the Forest Service sponsored a Farm Forestry Project in the Black Forest area which has since been discontinued.

The Soil Conservation Service supplies technical services in the development and application of conservation plans to farmers and ranchers who have organized soil conservation districts. Three such districts have been established to date with a total area within the watershed of 228,521 acres or 38 percent of the drainage basin. About 75 percent of the farm or ranch operators is included within the area of these districts.

With this technical aid the land operators are developing soil and water conservation plans and applying practices many of which contribute to the retardation of runoff and to soil erosion reduction. Practices currently being performed and considered of primary importance to flood control objectives include: streambank protection, range seeding, stockwater developments, terracing, diversions, contour farming, crop residue management, strip cropping, and land leveling.

In 1934-35, in cooperation with the Civilian Conservation Corps, a project was established in the Templeton Gap area to demonstrate on-the-ground agricultural practices and structural treatment for soil and water conservation.

The Production and Marketing Administration through its Agricultural Conservation Program branch has been carrying on a conservation program in the watershed by making direct aid available to land owners or operators for soil and water conserving practices. This program has resulted in the installation of many soil and water conservation measures. Practices considered of importance to the alleviation of flood and sediment problems which have been put into effect consist

of erosion control dams and ditches, terracing, installation of rock and brush dams, stock-water dams, establishment of fire guards, tree planting, fencing, riprapping of streambanks, pasture seeding, and grazing land management.

The Extension Service, through demonstrations, tours, farm visits, radio programs, newspaper articles, and 4-H programs, conducts educational activities for agricultural programs in the basin which result in the adoption or acceleration of soil and water conservation measures, some of which contribute to flood and sediment control. In various parts of the watershed, community planning committees have been established and flood control has been one of the problems considered by the committees.

Other agencies active within the watershed include the Farm Credit Administration which makes production and capital loans and the Farmers Home Administration which carries on its rehabilitation program and also makes production and capital loans to borrowers who enter into contracts involving farm management plans.

FLOOD AND SEDIMENT DAMAGES

Causes of Floods

Human factors have accentuated natural factors in increasing the frequency and size of floods and in increasing flood damage. The principal natural causes are the occurrence of high intensity summer storms which cause rapid rises in stream flow, the drainage pattern above Fountain which encourages rapid concentration of runoff, and the inherently low infiltration rates of many plains soils. Settlement was soon followed by deterioration of many of the uplands which caused

acceleration of surface runoff and erosion. With development, encroachment upon the flood plain has created continually increasing damageable values. Presettlement floods apparently consisted of relatively clear water moving slowly in a wide unrestricted flow over vegetated channels and naturally grassed waterways. More recent floods pass through eroded gullies and over raw slopes and cause extensive water and sediment damage to bottom land developments and improvements that have encroached upon the flood plain.

Grazing use of the vegetative cover is a problem of major significance in the plains area and on much of the individually owned mountain land. Overuse soon after settlement depleted the cover to such an extent that now a much smaller number of livestock keep the range in a poor condition. Plant vigor and density are decreasing and species of low palatability are increasing in number. As a result in many places native range vegetation is no longer able to hold the soil in place and erosion is accelerating.

Present management of dry-farm land does not permit maximum infiltration of precipitation and makes little provision for arresting erosion. Recent market conditions have caused the cultivation of former range land entirely unsuited for cropping. This removal of riparian vegetation together with inadequate water disposal and routing facilities are resulting in destructive gullying and bank cutting.

In the Black Forest area and on other timbered areas in private ownership, exploitative logging, unregulated grazing, and burning prevent satisfactory regrowth of the timber stand and adequate restoration of ground cover.

Many miles of road have been constructed without sufficient regard to good engineering procedure. Bridges and culverts are often inadequate; road ditches are becoming deep gullies; back slopes and berms are not stabilized; and many water disposal problems have developed.

Flood damage to urban property is largely due to channel restrictions and development of unprotected flood plain areas.

Flood History

Records and observations offer a fair picture of the flood history of Fountain River, Monument Creek, and Fountain Creek. From 1864 to 1947, six floods are reported to have occurred at Pueblo, seven at Colorado Springs, and six at Manitou Springs (table 2).

Numerous floods have been reported from various parts of the watershed. Damaging floods on tributary streams occur with regularity, several of which may come in any one year. Even though these are local in extent they are important in the aggregate due to their frequent occurrence.

Evaluated Damages

During the past 80 years, the productive value of 7,325 acres of fertile bottom land has been lost through bank cutting. This represents an average loss of 92 acres annually although the current rate of loss undoubtedly exceeds the long-time average. Urban losses are concentrated in Manitou Springs and vicinity where channel encroachments are pronounced and damageable values are high. Indirect damages result largely from losses in agricultural production, loss in revenue due to interruption of business, and additional costs of

Table 2. Major floods. Fountain River Watershed

Date of flood	Drainage	Remarks
June 10, 1864	Monument Creek	Caused loss of 13 lives. Estimated peak discharge at Colorado Springs, 40,000 c.f.s. and at Pueblo 45,000 c.f.s.
Summer 1880	Williams Canyon	Caused loss of 1 life at Manitou Springs.
July 1882	Williams Canyon	Damaged Manitou Springs.
July 25, 1885	Shooks Run	Caused loss of 1 life. 6,120 c.f.s. peak discharge from Shooks Run.
August 2, 1886	Monument Creek and Shooks Run	Estimated peak from Monument Creek was 40,000 c.f.s.
July 27, 1893	Fountain River	Peak discharge of 40,000 c.f.s. at Pueblo.
May 30, 1894	Fountain River	Similar to flood of July 27, 1893.
July 1897	Williams Canyon	Damaged Manitou Springs.
Summer 1897	Williams Canyon	Described as "severe." Damaged Manitou Springs.
August 5, 1902	Fountain Creek	Damaged Manitou Springs.
August 7, 1904	Local tributary north of Pueblo	9,640 c.f.s. from 6.1 square miles drainage. Failure of railroad bridge caused train wreck and loss of more than 100 lives.
June 3-4, 1921	Fountain River	Greatest flood of authentic record. Crest of flood, 35-50,000 c.f.s., reached Pueblo a few hours after the crest of a flood on Arkansas River which had a peak of 103,000 c.f.s. Combined flood caused loss of 78 lives and damage in amount of $10,000,000.
June 5, 1921	Fountain & Ruxton Cr. & Williams Canyon	Damaged Manitou Springs in amount of $110,300.
May 27, 1922	Shooks Run	Damaged eastern section of Colorado Springs.
July 29-30, 1932	Shooks Run	Damage to Colorado Springs in amount of $144,800.
May 30-31, 1935	Monument Creek	Maximum recorded at Colorado Springs. Estimated peak of 50,000 c.f.s.
May 10, 1947	Fountain Creek, Williams Canyon and vicinity	Caused loss of 1 life and damage in amount of $195,000 to Manitou Springs and vicinity. Most damaging in record of Manitou Springs.

rerouting traffic. Sedimentation damages include losses on the watershed and also damages on the Arkansas from where the Fountain enters that river to and including John Martin Reservoir. Canal and ditch sedimentation damages are based on the cost of removing deposits from irrigation works. Reservoir sedimentation damage is based on an annual estimated storage loss of 70 acre feet within the watershed and 75 acre feet in the John Martin Reservoir and the value of such space depletion which in turn is dependent upon the purpose the reservoirs serve. Table 3 is a summary of the average annual flood and sediment damages based upon 1947 prices. Damages which are not recurrable due to existing or authorized protective works are not included in the table.

Table 3. Summary of average annual flood and sediment damages. 1947

Item	Damage
	Dollars
Destruction of land by bank cutting	116,500
Loss of crops, buildings, fences, etc.	31,500
Damage to railroads, bridges, roads	66,500
Urban losses	16,200
Indirect	32,600
Canal and ditch sedimentation damage	23,300
Sedimentation damage to reservoirs	13,900
Total average annual	300,500

Nonevaluated Damages

In the aggregate, the nonevaluated damages probably total as much as the evaluated losses. Past floods have caused 196 deaths including 78 lives lost in Pueblo as the result of the 1921 joint flood on the Arkansas and Fountain Rivers and local residents are apprehensive of future floods. Several lives have been lost in the town of Manitou Springs and vicinity and only by fortunate circumstances has greater loss of life been avoided. The constantly present danger to human life in this area is increasing due to further development and encroachment upon the flood plain within the narrow confines of Williams and Black Canyons and local interests are unable to cope with the problem.

Some irrigation systems have been abandoned due to excessive maintenance costs of diversion structures and inability to irrigate resulting in loss of irrigation water and damage or loss of crops until such flood damage is repaired. As a result of these occurrences lands adjacent to some streams have been relegated to lower use. Flood damaged roads constitute traffic hazards and summer tourist trade may be discouraged because of adverse flood publicity. Loss of topsoil with its high concentration of plant nutrients through erosion represents an enormous loss.

PLAN OF IMPROVEMENT

Remedial Measures

In developing the remedial program several methods of treatment were considered. Based on physical features and opportunities favorable to the restoration and retention of an adequate vegetal cover as well as to complementary structural measures, the most effective

program resulted from integrating vegetal treatment with certain complementary structural works. The latter are necessary to afford immediate relief to the people within the area until the vegetal measures become fully effective. They will also reduce losses of valuable land from bank cutting and other forms of erosion, protect urban developments, and lessen road damages. The land treatment phase, while slower in becoming effective, will heal critical flood and silt source areas, stabilize soil, reduce surface runoff, enhance the water resource, and progressively reduce maintenance costs of the structural phase which will be initially high.

The proposed program combines the physical and biological characteristics of the watershed and provides immediate relief to the affected people besides many other concomitant conservation benefits.

The estimated quantities of the proposed remedial measures are over and above those which it is estimated will be accomplished under going programs of all Federal agencies during the installation period. The costs, which include maintenance during the 10-year installation period, are based on 1947 prices.

The retirement of 5,220 acres of privately owned dry-farm land to pasture is recommended. In order to slow down excessive runoff and stop soil movement, this acreage will be treated first with dikes or diversions and then seeded to adapted grass species at a cost of about $32,000. Two hundred and sixty miles of terraces costing approximately $51,000 will be constructed on dry-farm land to remain in crop production, and 1,460 miles on pasture and range lands costing about $79,000 where sheet flows of surface runoff are causing lateral sloughing of channels and the

development of upland steplike head cuts. Three hundred and eighty water spreading and diversion structures at an estimated cost of $322,000 will be constructed on range and cropland to slow down surface runoff and increase infiltration as well as greatly decrease sediment originating from these areas.

In the mountainous portion of the watershed 3,260 acres will be reforested at a cost of approximately $130,000. These lands are scattered old burn areas presently supporting some shrub growth and a small amount of aspen. Some of these lands are presently being grazed. Additional fire protection, costing about $4,000, will be supplied on about 42,000 acres of privately owned woodland and 90 miles of fence costing about $44,000 should be installed. The purchase of 4,880 acres of private land, at an estimated cost of $55,000, in the critical area above Manitou is recommended. These lands are high potential flood and sediment source areas due to inherently unstable soils on which there is an absence of cover due to past timber cutting, overgrazing, and cropping.

Provision is made for the purchase of water rights, or rights to the use of water, that may be required as the result of installation of the recommended measures at a cost of about $2,000.

For the protection of Manitou, debris dams should be constructed on Fountain Creek, Black Creek, and Williams Canyon and one large existing debris basin should be adequately maintained. In addition, the

recommendations include certain road relocations and substantial channel improvements on Fountain and Ruxton Creeks and Williams Canyon, including the construction of improved channel sections, removal of restrictions, deepening of channels, construction of grade weirs, and protection of banks. Total cost of this work will be about $721,000.

The proposed road improvement measures, costing approximately $361,000, consist of installing, resetting, and replacing culverts and bridges; constructing diversion spreading ditches, interception ditches, borrow ditch checks; stabilizing cuts and fills by seeding and wattling; installing curbs and revetments; and treating and obliterating abandoned roads.

In order to overcome certain of the characteristics which contribute to floods and erosion, 2,800 small flood detention dams costing about $1,337,000 and capable of temporarily retarding about 20 acre feet of surface runoff per section of land will be constructed. Thirteen miles of plantings, fences, tetrahedrons, or other bank protection works will be installed in drainageways and channels at appropriate locations to reduce bank cutting and erosion at a cost of approximately $261,000.

Technical services will be provided to aid in planning and applying the program. Educational assistance will also be made available to inform land operators of the program and its application and to assist in obtaining the cooperation of these operators in applying and maintaining program measures. During the installation period there will be a need for the cooperative integration of the various parts of the program and evaluation of the effects of the installations.

The total installation cost of the entire recommended program, shown in table 4 is about $4,020,000 of which $3,439,000 is the Federal share.

Table 4. Estimated costs for installation of program including maintenance during the installation period

Over-all treatment measures	Cost
	Dollars
Land treatment	1/1,090,000
Structural works	2/2,875,000
Acquisition	55,000
Total	4,020,000

1/ Includes 32.7 percent for technical services, educational assistance, program integration, and program evaluation.

2/ Includes 9.3 percent for technical services, program integration, and program evaluation.

Maintenance of Program

After installation of the recommended program, maintenance will be necessary in order to perpetuate its beneficial effects. Complementary measures must be kept in good repair until the restorative measures on the watershed become fully effective in reducing flood and sediment damages. The estimated annual cost of maintaining the recommended program after the installation period is $42,600 of which $4,900 is the Federal share.

Participation in Program

The Federal Government will pay the cost of all measures installed on Federally owned land and lands in the process of being acquired, acquisition of critical lands, program integration, program evaluation, purchase of water rights or rights to the use of water and technical services required on croplands, range lands, and for installation of structural features. On non-Federal lands the Federal Government will pay up to 40 percent for fencing, terracing, and seeding; up to 90 percent for installation of water spreaders, diversions, detention dams, and works for the protection of Manitou Springs; up to 66 percent for installation of streambank protection measures; and up to 50 percent of all other measures applied on non-Federal lands and will cooperate with the State of Colorado in providing technical services for private timberlands and educational assistance needed to install and maintain the program. A portion of the cost of applying land treatment measures to privately owned land will be provided in the form of direct aids.

The balance of the costs for measures on non-Federal lands will be borne by non-Federal interests.

Annual maintenance will be allocated as follows: the Federal Government will pay the costs of maintenance for all measures installed on Federally owned lands and up to one-half such costs for cooperative fire protection on non-Federal lands. In addition, the Federal Government may participate in the costs of providing technical services and educational assistance on non-Federal lands which

may later be required to perpetuate the program on these lands. Non-Federal interests will provide the balance of maintenance required for fire protection and for all other measures installed on lands in non-Federal ownership.

It is anticipated that the recommended measures for non-Federal land will be installed under cooperative arrangements with agencies acceptable to the Secretary of Agriculture. Local interests are to be required to furnish without cost to the United States all requisite rights-of-way and easements on non-Federal lands, and hold and save the United States free from all claims for damage incident to the construction and operation of the recommended program for flood control.

Water rights or rights to the use of water will be acquired in accordance with existing state laws. The Secretary of Agriculture and the head of any other Federal Department concerned may construct such buildings and other improvements as are needed to carry out the measures included in the recommended program.

In preparing the recommended program and in developing the measures necessary to achieve the benefits claimed, it has been assumed that all pertinent and related activities currently in progress in the watershed will be continued on about their present scale inasmuch

as the program recommended is over and above all current work. In carrying out the program, it is proposed to take full advantage of opportunities to utilize the services of the various conservation agencies, locally in the state as well as those in the U. S. Department of Agriculture and other Federal Departments.

The authority of the Secretary of Agriculture or of the head of any other Federal Department concerned to prosecute the recommended program shall be supplemental to all other authority vested in him, and nothing in this report shall be construed to limit the exercise of powers heretofore or hereafter conferred on him by law to carry out any of the measures described herein or any other measures that are similar or related to the measures described herein.

It is believed that only through the measures and practices recommended for the watershed can widespread and beneficial water-flow retardation and soil erosion prevention be achieved. However, the Secretary of Agriculture and the head of any other Federal Department concerned may make such modifications or substitutions of the measures described herein as may be deemed advisable due to changed physical or economic conditions or improved techniques whenever he determines that such action will be in furtherance of the objectives of the recommended program.

Program Benefits

When fully established, the interrelated remedial control measures will reduce flood and sediment damages originating from excess runoff and erosion on the watershed as well as increase the agricultural production of the area.

It is estimated that on the average, flood peaks will be reduced by about 44 percent and sedimentation rates about 58 percent. Flood and sediment damages to roads resulting in high maintenance costs will be reduced about 88 percent. About a 66 percent reduction is expected in future flood and sediment damages.

Other beneficial results will accrue from the program. The hazard of loss of life will be reduced. The reduction in flood hazards will enable more stable planning and permit the highest use of land with a minimum of adjustment to the uncertainties created by constant fear of flood losses. The interruption of irrigation systems by floods and fear of crop loss will be alleviated and productivity of watershed lands will be increased. Important recreational developments and values will be protected and enhanced.

Benefits are based on the difference between expected future damages with and without a program less the costs of irrigation water which may be lost as a result of installing the recommended program. Annual net benefits from the recommended program will total about $314,400 of which those related to sediment reduction and water control are estimated at $175,000 annually. Many other benefits ascribable to the program cannot be readily evaluated in monetary terms. Future annual benefits by types of benefits are shown in table 5.

Much of the relief and protection from damages will at first be largely dependent upon the structural phases of the program. In the early stages, maintenance costs to preserve the maximum effectiveness of certain structural works will be relatively high. As the land treatment measures become increasingly effective, these costs will

Table 5. Estimated annual value of future benefits with program

Type	Amount
Agricultural	$ 79,400
Railroads	8,800
Roads and bridges	34,300
Urban	13,000
Indirect	20,300
Sedimentation	
Reservoir	7,200
Irrigation distribution system	12,000
Subtotal	$175,000
Range land conservation	26,500
Cropland conservation	76,200
Timber conservation	39,800
Total	$317,500
Less costs of water loss	3,100
Net benefits attributable to accelerated program	$314,400

materially decrease and at later stages any loss in effective capacity of these structures will be offset by compensatory reduction in runoff and sediment movement due to the land treatment measures. The time period during which protection will rely largely on structural measures will vary with conditions in the watershed. In some areas the progress of vegetal controls will be greatly accelerated by installing such complementary measures as terraces, water spreaders, diversions, channel works, and other recommended measures, while in other areas natural vegetation will become effective within a very short time after some of the measures and controls are installed.

The program as outlined therefore relies for its full effectiveness upon a series of integrated dependent measures which combine to afford immediate as well as long time relief from the flood and sediment damages in the basin.

Comparison of Benefits and Costs of Program

Benefit-cost ratios were computed upon the basis of average price relationships expected to prevail during the period 1955 to 1965. A 2½ percent interest rate was used to convert Federal, state, and local installation costs to an average annual cost and a 4 percent interest rate was used to convert private installation costs to an average annual cost. On this basis the annual benefits total $189,700 and the annual costs of installation and maintenance total $111,800. The ratio of over-all benefits to costs is 1.70:1.

Recommendations

It is recommended that the Federal Government undertake the installation of a flood control program within the Fountain River

watershed to reduce surface runoff, erosion, and sediment production at a Federal cost of about $3,439,000 for installation and $4,900 annually for maintenance.

It is expected that local interests will contribute approximately $581,000 for installation and $37,700 annually for maintenance.

The program herein recommended includes the intensification, acceleration, or adaptation of certain activities under the current programs of Federal agencies in the watershed, and additional measures not now regularly carried out in such programs, all of which are necessary to complete a balanced runoff and waterflow retardation and erosion control program for the watershed. It is recommended that the Secretary of Agriculture be authorized to carry out all of this program except the part which is proposed for installation on land under the jurisdiction of a Federal agency other than the Department of Agriculture. It is further recommended that the head of such other Federal agency be authorized to carry out the part of the program which is proposed for installation on land under the jurisdiction of such agency. The extent to which the work recommended in this program for which the Secretary of Agriculture is to be responsible will be carried out under the Flood Control Act as requested herein or under other authorities will be considered by the Secretary in requesting appropriations for the prosecution of the program. Although the current activities of Federal agencies in the watershed which are primarily related to the objectives of the Flood Control Act are not included in the program herein specifically recommended, the program is based on the continuation of such activities at least at their present level. The extent

which the practices and measures included in the recommended program may be carried out by the acceleration, intensification, or adaptation of certain activities under the current programs of Federal agencies in the watershed will be taken into account in requesting appropriations for the prosecution of the program.

UNITED STATES DEPARTMENT OF AGRICULTURE

APPENDIX
SURVEY REPORT
FOUNTAIN RIVER WATERSHED
COLORADO
1950

(AGRICULTURE - OGDEN)

UNITED STATES DEPARTMENT OF AGRICULTURE

B

APPENDIX TO FLOOD CONTROL SURVEY REPORT ON PROGRAM OF RUNOFF AND WATER FLOW RETARDATION AND SOIL EROSION PREVENTION FOR FLOOD CONTROL PURPOSES FOUNTAIN RIVER WATERSHED, COLORADO

In compliance with
Section 6 of the Flood Control Act, June 22, 1936, Public No. 738 74th Congress; as amended June 28, 1938, Public No. 761, 75th Congress

17538

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INTRODUCTION

1. This appendix supplements the Survey Report on a program for surface runoff retardation and soil erosion prevention in the interest of flood control on Fountain River Watershed, Colorado. It covers the watershed management and related features of a comprehensive plan of improvement together with the basic data for the analysis and evaluation of the recommended program.

GENERAL CHARACTER OF THE DRAINAGE BASIN

LOCATION, SIZE, AND SHAPE

2. The Fountain River, a tributary of the Arkansas River, drains an area north of Pueblo in central Colorado. Its watershed includes parts of El Paso, Pueblo, Teller, and Douglas Counties. The principal tributaries originate in the mountains of the Front Range east and north of Pikes Peak and in the Black Forest along the Arkansas and South Platte Divide. Monument Creek, the northern part of the main stem, flows south from Palmer Lake to Colorado Springs where it joins Fountain Creek to form Fountain River. The river has a southeasterly course to its confluence with the Arkansas River at Pueblo. (Map 1.)

3. The total area of the drainage is 927 square miles of which 239 square miles are drained by Monument Creek and 120 square miles by Fountain Creek. Other major tributaries are Jimmy Camp Creek, Sand Creek, Little Fountain Creek, Woodbury Creek, Dry Creek, and Youngs Hollow. The length of the basin from Palmer Lake to Pueblo is about 65 miles and the maximum width is about 25 miles in the vicinity of Colorado Springs.

4. The shape of the watershed approximates that of an acute oblique triangle with the apex at Pueblo. This characteristic constitutes a very

favorable condition for the production of high peak flows at points along the main stream north of Fountain. South of Fountain, as the drainage narrows, it is less favorable to the production of high flood flows.

5. The drainage area of Monument Creek above Colorado Springs is compact and so shaped as to bring about the quick concentration and co-ordination of tributary inflow along the main stream.

PHYSIOGRAPHY

6. Diverse topographic forms including glaciated highlands, peneplains, youthful valleys, and late mature to old erosion surfaces are features of the watershed. Two widely different physiographic provinces are represented. The front of the Southern Rocky Mountain Province rises rather abruptly 2,000 to 7,000 feet above the plains, forming a great scarp that crosses the northwestern part of the watershed where the mountainous surface reaches an elevation of 14,100 feet at Pikes Peak. (Map 2) This area is maturely dissected while the valleys are narrow, steep-walled and rather straight evidencing regional uplift and rejuvenation of the streams. The divides are broad, rounded remnants of an old peneplain above which the highest peaks rise as monadnocks. During Pleistocene times these mountains were centers of glaciation and glacial deposits remain in many of the valleys at altitudes above 9,500 feet. With the exception of these debris-choked valleys, the area is well drained.

7. The foothills are a narrow zone of transition from mountains to plains. In the Manitou embayment, the foothills are a series of ragged, parallel, north-south trending ridges. Elsewhere they consist of narrow, gently sloping mesas.


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FOREST SERVICE
INTERMOUNTAIN FOREST & RANGE EXPERIMENT STATION
OGDEN, UTAH
FLOOD CONTROL SURVEY
FOUNTAIN RIVER WATERSHED - COLORADO
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WOODLAND PARK
EDGERTON
BREECH
FALCON
GREEN MTN FALLS
CASCADE
TEMPLETON GAP
MANITOU
COLORADO SPRINGS
BROADMOOR
PETERSON FIELD
EL PASO CO
TELLER CO
EL PASO PUEBLO
COUNTY COUNTY
TELLER COUNTY
EL PASO COUNTY
NORTHERN PLAINS AREA
SOUTHERN PLAINS AREA
PIKE NATIONAL FOREST
MOUNTAINOUS AREA
CAMP CARSON
FOUNTAIN
BUTTES
PINON
PUEBLO
ARKANSAS RIVER
FOUNTAIN RIVER
CARROL LAKES
LAKE MORAINE
Monument Creek
North Monument
Beaver Creek
Cottonwood
Sand Creek
Fountain Creek
Black Squirrel Cr.
Jimmy Camp Creek


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TOPOGRAPHY
SUBMITTED M.E.B. 3-11-48 DATE
APPROVED M.E.B. 3-12-48 DATE
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PALMER LAKE
MONUMENT
HUSTED
WOODLAND PARK
EDGERTON
BREECH
FALCON
MANITOU
COLORADO SPRINGS
FOUNTAIN
BUTTES
EL PASO COUNTY
PUEBLO COUNTY
PINON
PUEBLO
ARKANSAS RIVER
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8. The balance of the watershed, which lies in the Colorado Piedmont section of the Great Plains Province, exhibits many features of an old erosion surface. The streams flow in meandering courses in broad, open valleys. North of a series of low irregular escarpments in the latitude of Colorado Springs, the plains area is underlain by Dawson arkose and the surface is rolling with long, low dividing ridges between valleys. South of these escarpments, the plains are developed principally on Pierre shale and are made up of long gentle slopes reaching from the watershed boundary to the main stem, with broad low divides between valleys except where mesas capped by gravel stand with steeper peripheral slopes.

SURVEY METHODS AND SOURCES OF DATA

GENERAL

9. During the course of the survey, data were obtained from many sources and by various methods. A thorough review of existing literature was one of the first survey activities. This review covered reports prepared by the Department of Agriculture, Corps of Engineers, Bureau of the Census, Weather Bureau, Geological Survey, State of Colorado, city of Colorado Springs, and other agencies. Pertinent data were abstracted from unpublished material and office files of these and other groups. Every effort was made to obtain reliable information and opinions from responsible individuals, in particular, technicians engaged in similar fields, public officials dealing with flood and related problems, and dependable farm owners and operators of watershed lands.

10. Field surveys were made of watershed conditions, damage areas, reservoirs, road conditions, and other factors together with types of

remedial measures which might be applied. Aerial photographs were available for the entire watershed and full use was made of these in all field work.

WATERSHED MANAGEMENT AND ENGINEERING

Inventory of Watershed Conditions

11. After the survey party had assembled all pertinent material from outside sources, field surveys were made to provide other essential information. Using aerial photographs as a base and working over the entire watershed in the field, land conditions were delineated and maps prepared which presented detailed information on location of 11 soil groups, 5 slope groups, 14 erosion classes, and 12 vegetative cover types including cropland. Units as small as 10 acres were recognized.

12. Early field work revealed that loss of land through bank cutting was occurring over extensive reaches of the main stem between Colorado Springs and Pueblo and also on many of the tributary waterways. Considerable data were secured from old time residents as well as local technicians familiar with this problem and several channel reaches were examined in detail. Two sets of aerial pictures taken in 1937 and 1947 along the main channel permitted a detailed comparison of the changes in channel conditions, locations, bottom land use, etc. which had taken place during the 10-year interval.

13. A high percentage of the roads were covered by a reconnaissance method. Representative sample sections in each construction class were then selected for detailed study and program development. All measures except those pertaining to bridges were expanded from the sample sections; the bridge inventory covered the entire watershed.

14. A field examination and an office analysis were made of the watershed area above Manitou Springs for the purpose of developing measures designed to protect the town and surrounding areas from extensive flood damage. Such factors as the physiographic features, topography, and drainage network were considered in relation to their effect on the probable magnitude and synchronism of flood peaks. The geology, soil, vegetative cover condition and trend as well as past flood and sediment source areas were given consideration. The study also covered the existing flood channels in the town, their probable adequacy, and methods of increasing their capacity.

15. Finally, field discussions with soil conservation district personnel, the farm forester, and ranch and farm operators helped to round out the over-all picture of watershed conditions.

Basis for Program Design

16. When consideration was given to specific corrective measures and practices which might be influential in retarding surface runoff and in preventing soil erosion, special attention was directed to those measures which had already been applied, on a limited basis, to land in and adjacent to the watershed. Measures installed 10 to 15 years ago on both public and private lands under the Emergency Conservation Work program, were examined and studied. Many of these measures have proved highly successful whereas others have not accomplished their intended purposes. These measures, together with those installed as parts of the soil conservation district, national forest, and agricultural conservation programs, constituted a sound beginning for the planning of a program in the interest of flood control. Included in these various

programs were such measures and practices as land conversions, range reseeding, reforestation, pasture furrows and terraces, improved management of both farm land and forest, stock tank installation, stream bank protection, crop rotation, terraces, and similar items.

17. An inventory was made of soil conservation district plans to determine the desirability and feasibility of other flood control measures and practices which had not been installed due to the financial status of the land owner and his reluctance to spend his funds for measures from which he himself receives little or no benefit.

18. Due to the inherent characteristics of the soil and cover conditions in the plains area, it became apparent that normal land treatment measures alone would not increase infiltration and reduce surface runoff by an amount commensurate with the downstream values in need in of protection. Sample watersheds therefore were selected for special study. Youngs Hollow was chosen as representative of the southern plains area, and Kettle and Pine Creeks as typical of the northern plains area. A complete flood control program was developed for each selected area and verified by examinations of other tributaries. The program included the usual land treatment measures and, in addition, provided for surface storage of excess runoff through a system of small flood detention dams and for water spreading through use of major spreaders and diversions. Water spreaders were relied upon more heavily in the southern section due to presence of favorable spreading areas and absence of a sufficient number of detention dam sites. Data thus secured on diversions, spreaders, and detention dams in the selected subwatersheds were expanded to the related plains sections of the Fountain River drainage.

19. On-site inspection of areas in need of streambank protection, diversion structures, and tetrahedrons together with an appraisal of limited work of this type already accomplished, formed the basis upon which these measures were incorporated in the flood control program.

20. The road improvement measures were based on actual field examinations of portions of roads in need of treatment. Analyses were made of treatments already applied on a section of highway near Woodland Park just west of the watershed and on scattered sections of other roads in the drainage on which similar measures have been installed.

21. The engineering measures designed for the protection of Manitou were based on treatments and program installed in similar areas with due regard to physical limitations, anticipated benefits, and ultimate costs.

FLOOD DAMAGE AND ECONOMIC DATA

Assembly of Existing Data

22. The principal secondary sources of flood damage and economic data included Corps of Engineers, Bureau of the Census, summaries of survey questionnaires, records of public hearings, and records of local public officials and agencies. These sources were generally adequate for damages which have resulted from major floods but contained practically no information relative to minor flows and tributary damage.

23. A large part of the miscellaneous economic data covering types and sizes of farms, market prices for farm products, production rates, etc. was taken from records of county clerks, assessors, commissioners, Agricultural Adjustment Administration files, and public

records. These data were supplemented by extensive field contacts and discussions with farmer groups and national forest personnel.

Types of Damage Considered

General

24. In the determination of expected flood damages, consideration was given to the effects of preventive measures already installed. Included in these measures were the improved channel through Colorado Springs with a designed capacity of 50,000 c.f.s., the authorized Corps of Engineers project for the Templeton Gap area, bank protection work and improved channel in vicinity of Pueblo, and the various reservoirs and debris basins already constructed.

25. It is expected that the above-mentioned improvements will greatly reduce future flood damage to Colorado Springs and Pueblo. Future potential damage to these two cities has not been included in subsequent development of expected future damages as outlined in this report. However, it is pointed out that flows in excess of maximum known discharges at these points will cause extensive damage. The Department of Agriculture program as proposed in this report will have a beneficial effect in reducing flood flows in excess of 50,000 c.f.s. at Colorado Springs and 30,000 c.f.s. at Pueblo, however, such effects have not been evaluated in this appraisal.

Agricultural

26. The agricultural damages sustained on Fountain River watershed are of three principal types. First, complete loss of, or reduction in, productive value of flood plain lands. This type of damage is experienced through destruction of land by streambank cutting, by

deposition of sterile sediment and scour action of water and debris. Second, losses resulting from damage to irrigation works. In this group are such losses as destruction of diversion dams and take-outs, damage to head gates, and deposition of sediment in canals and lateral ditches. Third, damage to crops and improvements by overbank flow of water. These damages occur whenever crops are inundated, planting is delayed, fences are washed out, livestock is lost, equipment is damaged, and other improvements are injured.

Municipal

27. Municipal damage to Manitou Springs and some other smaller communities occurs at rather frequent intervals. Losses consist of such items as damage to buildings and furnishings, real estate improvements, streets, sidewalks, water mains, power facilities, and equipment and protection works.

Railroad, road, and bridge

28. Damages to railroads, roads, and bridges consist of such items as repairs and replacement of washed-out roadbeds; repair, replacement, and enlargement of bridges, resetting of culverts and drainage structures; loss of equipment, rolling stock, and improvements; providing emergency protection works, and increased general maintenance.

Reservoir

29. Damages are based on reservoir replacement costs with the exception of John Martin Reservoir. For the latter reservoir the net value of irrigated crops was used to evaluate depletion of the conservation pool with loss of flood control storage reflected by reduced flood reduction benefits.

Indirect

30. These damages are losses arising from direct flood damages but not directly attributable to the flood itself. They include losses due to interruption of business, rerouting of traffic and decreased property values; costs of evacuation and reentering premises; and costs of relief, policing, and caring for the sick and injured.

Nonevaluated damages

31. Loss of human life is the most important of the nonevaluated damages occurring on the Fountain River watershed. Other damages not generally susceptible of monetary evaluation include such items as: increase in susceptibility to sickness and disease as result of impairment of water supplies and sewage disposal facilities; land owner's fear of losing his livelihood, crops, and home; traffic hazards resulting from weakened bridges and road wash-outs; and loss of irrigation water and possible crop damage or loss due to washing out of diversion structures.

Methods of Determining Damages

32. Insofar as possible, all damages caused by past floods were recorded in the field. When sampled, the sampling was done in such a manner that reasonably reliable estimates could be made. Limitations in recorded data and nature of damages generally made it impossible to assign damages to individual floods. This was especially true of minor floods on tributaries, several of which may occur in any one year. In order to have a common basis of comparison, damages were expressed in terms of average annual values.

Agricultural damages

33. Agricultural damages resulting from complete loss of, or reduction in, productive value of irrigated and other flood plain lands

as result of streambank cutting were obtained from a study of channel conditions and estimates of types and values of crops normally grown on similar undamaged areas. In order to calculate the annual damage from land loss, it was necessary to determine (1) the total amount of land lost, (2) the period over which the loss was experienced, and (3) the value of crops produced on the land before destruction.

34. The present area in channel and river wash gravels along the main stem and the principal tributaries was taken from the detailed soils map. In the case of the lesser tributaries, the area was calculated from the miles of tributary streams and an estimated average channel width. It was assumed that the original main stream channel was 70 feet wide which is considerably in excess of the 35 to 40 feet estimated by old long-time residents. Likewise, similar conservative estimates of original channel widths were made for the tributaries. The difference between the total present area in channel and gravel wash and the estimated original channel area was a measure of the total amount of land lost through lateral cutting of the river and its tributary streams.

35. The total area lost divided by numbers of years since the start of active agricultural development established the annual rate of loss. It is realized that lateral cutting probably did not become serious until many years after early settlement; however, by assuming a present rate equal to the long time average, a conservative figure is used. Without treatment, it is expected that the past rate of land destruction will continue into the future until virtually all bottom land is destroyed. The evaluation has been carried forward only for

100 years at which time there will remain substantial areas of undamaged land.

36. The gross value of the crops which would have been produced on the lost land was used as a measure of the damage. Crops, yields, value, and weighted average value per acre of crops grown on bottom lands of the main stem were secured from field surveys, agricultural statistics, county agents, the Colorado Agricultural Experiment Station, and the Corps of Engineers. As most of the tributary bottom land is in pasture and dry land cultivation, values based on these uses were applied for tributary losses although there are many small acreages of irrigated land bordering the northern tributaries. Future expected annual losses were conservatively obtained by projecting present losses 100 years into the future and obtaining a simple average.

37. Damages suffered by irrigation interests include such direct flood losses as destruction of diversion structures and head gates as well as sedimentation damage to canals and laterals, and interruption of water supply during the growing season. Damages experienced along the main stem were taken from Corps of Engineers data and adjusted to a common base value. Sedimentation damage, reflected by the costs of cleaning canals, was secured by field questionnaire during the course of the survey. Officials and owners of canals and ditches which serve 26 percent of the irrigated acreage furnished estimates of annual costs of sediment removal. These figures were used as a sample and expanded to the total irrigated land.

38. Estimates of damage to agriculture from overbank flooding on the main stem were adapted from Corps of Engineers figures. These

damages were based largely on the floods of 1921, 1932, 1935, and 1936. A field survey was made to ascertain the extent of damage from flooding in the tributary areas. Damages in these areas occur much more frequently than along the main stem but damageable areas are more limited. The field survey consisted of contacts with land owners and operators in areas which, on the basis of location, topography, and drainage, might be expected to suffer from overbank flooding.

Municipal damages

39. Flood damages to Manitou Springs, the area adjoining Fountain Creek above its confluence with Monument Creek, and other urban and suburban areas were based on survey estimates obtained by local inquiry, from analysis of published figures and newspaper articles, and from detailed study of the damage caused by the May 10, 1947 flood which occurred while the survey was in progress. Nine damaging floods are known to have occurred to Manitou and vicinity since 1880. Estimates of damages were available for five of the floods, all of which occurred since 1902. Proper adjustments were made so that all figures were based on 1947 values.

Railroad, road, and bridge damage

40. Railroad maintenance officials furnished estimates of flood damages to their respective properties within the watershed. Average annual damages were estimated for each company and then summated. The Denver and Rio Grande Western Railroad in its north-south crossing of the watershed suffers many wash-outs and traffic delays as well as excessive costs for fence maintenance and removal of sediment and debris

from rights-of-way and drainage outlets. The Midland Railroad which operates a line through the Ute Pass from Colorado Springs to Cripple Creek is especially vulnerable to side washes and bridge damage. The Atchison, Topeka, and Santa Fe suffers similar losses but to a lesser degree.

41. Estimates of flood damages to roads and bridges were based on detailed discussions with state, county, and Federal road officials. Records were checked and although repair of flood damage is not generally recorded separately, it was possible to make reasonable separations in maintenance costs. These separations were made after giving full consideration to recorded storms and to recollections of responsible individuals. In many cases, the repair of flood damage to roads and bridges constitutes the only maintenance cost.

Indirect damages

42. Estimates of indirect losses were based on field data and past experience on other flood damage studies as to the proportionate relationship of indirect to direct losses for the various types of damage involved.

Sedimentation damage

43. Rates of sediment accumulation in reservoirs on the Fountain River watershed were determined from field studies of a few selected samples and from published data on surveys of reservoirs in similar areas. These rates were related to the life expectancy of the reservoirs and converted to damage figures based on 1947 replacement costs. All the reservoirs are relatively small and are used for all conceivable purposes. An evaluation based on the wealth created by the reservoirs

would give a much higher damage figure, however, due to the many purposes they serve, such an evaluation would be extremely difficult. Use of a replacement value results in a very conservative estimate.

44. Rates of Fountain River sediment accumulation John Martin Reservoir on the Arkansas River were determined from an analysis of sediment samples obtained by the Corps of Engineers. The evaluation of damages was based on the anticipated loss in terms of net values of crops produced in case of depletion of the conservation pool and upon the expected flood reduction benefits in case of flood control storage.

45. The damage caused by Fountain River sediments to irrigation projects between Pueblo and John Martin Reservoir was determined by computing the relative amounts of Fountain River sediment which enter the irrigation canals and by appraising the damage on the basis of cleaning costs.

HYDROLOGY

Determination of Infiltration Rates

46. Infiltration rates for the mountainous portion of the watershed were determined from an analysis of numerous infiltration studies made on comparable soils at the Manitou Experimental Forest over a period of several years. (9)[1/]

47. Immediately before the survey, infiltration runs were made just outside the watershed on three major soil groups which extend into the Fountain River drainage and which comprise a considerable portion of the plains section. Twenty runs were made on each group under pasture

1/ Numbers in parentheses refer to items listed in bibliography.

and cultivated conditions, a total of 120 runs. Five factors appeared to have a major effect on infiltration, namely: texture of topsoil, permeability of subsoil, organic matter, plant cover density, and erosion condition. To each of these factors was assigned a numerical value based on qualitative value of high, medium, and low in such a manner that a high value reflected good infiltration quality and a low value, poor infiltration quality. Values for the five factors were assigned to each infiltration run and then totalled. The total became a relative index for the infiltration rate as measured at the end of each particular wet run (fc).

48. The resulting index for each run was plotted over infiltration rate for the three soils and two land uses. The relationships thus established were used to determine average infiltration rates for the three soil groups. By representative field inspection, relative indices were established for the other soil groups in the plains under present conditions and for all soils under expected future conditions. Changes in organic matter and in plant cover density were the only two factors contributing to the difference between present and future relative indices. The assigned indices together with the index-infiltration relationship already established were used to determine present and future infiltration rates for pasture and cultivated land in the soil groups. The proportion of cultivated land to pasture land in each soil group was used in computing the over-all rate (fc) for each soil as listed in table 7.

Infiltration Curves

49. Final infiltration rates were developed for the major soil groups within the watershed. All curves were averaged into one composite

shape which was used with the various final infiltration values. In determining the effects of the remedial program as reflected in increased values of the final infiltration rates the curves were translated upward vertically. Figure 1, shows an example of the typical curve.

Design Storms

50. In order to determine amounts of precipitation excess to be considered under present conditions and after the establishment of a program, it was necessary to develop rainfall patterns characteristic to the watershed. Original recording rain gage charts from all hydrologic network stations in the vicinity were secured and all significant rains tabulated. Some 225 storms were thereby available for study.

51. The average storm was based upon the establishment of categories ranging from 0.50 to 2.50+ inches selecting rains for each classification on the basis of intensities during 1-hour periods. In other words, all rains containing similar intensities for a 1-hour period were grouped together without regard to the total amount of rainfall recorded. It developed that, using this method of grouping, a definite pattern existed both in terms of intensities during various time intervals and in terms of total rainfall during the storm period.

52. From these data composite histograms of storm rainfall were developed for rains totalling 0.75, 1.00, 1.50, 2.00, and 2.50 inches. It might also be mentioned that in considering the beginning and ending of a particular rain, those portions occurring at intensities well below apparent infiltration rates were not included. Only the runoff producing block of rainfall was used. This procedure resulted in the

consideration of only the significant portions of any given storm and often eliminated parts that would tend to distort the true picture.

53. This study indicated that the maximum intensities of rainfall in this locality occurred at or very near the beginning of precipitation for rains up to 2.00 inches. The maximum intensities of rainfall during larger storms characteristically occurred after from one-fourth to one-third of the storm period had passed. During the very largest storms of unknown frequency, there apparently was no consistency in the time of occurrence of maximum intensity, rather the precipitation appeared to fall in a series of "blocks" between which the intensity was relatively low. Figure 1, shows the typical pattern for design storms.

Precipitation Excess

54. Having developed typical infiltration curves and rainfall patterns, values of the excess rainfall for each soil group under three of the rainfall classifications were then determined. Only the 1.50-, 2.00-, and 2.50-inch rains were used since storms of lesser magnitude do not result in flood runoff worthy of consideration in this report. The typical infiltration curve under present conditions was inserted into each histogram of rainfall and precipitation excess calculated. This procedure was repeated using curves developed for conditions after the program had become established. Thus the amounts of runoff from each soil group that might be expected under present conditions and after the establishment of a program were determined (fig. 1). Precipitation excess values both under present conditions and with a program for each soil group within the sample watersheds and within the entire watershed,

FIGURE 1 PRECIPITATION EXCESS FOR DESIGN STORMS
FOUNTAIN RIVER WATERSHED, COLORADO

were then weighed in accordance with the extent of each soil group. Thus weighted values of precipitation excess were obtained.

Hydrographs

55. Although short runoff records were available near Fountain and Pueblo on the main stem of Fountain River, few gaged records were available on tributary watersheds. In order to evaluate the effect of the remedial program on flood peaks and sediment production from subareas, it became necessary to develop hydrographs of runoff that would be typical of those to be expected from watersheds above small detention dams. The procedure was as follows:

a. To determine the average size of watersheds under consideration the area above a number of field located detention dams was measured from the maps of Youngs Hollow, Pine, and Kettle Creeks. Those areas were then averaged to provide a basis for hydrograph development.

b. Data from two experimental watersheds located near Colorado Springs were secured and analyzed to determine the probable shape of the hydrograph typical of watersheds above the detention dams.

c. Considering the sizes, shapes, and other physiographic characteristics of the experimental watersheds as compared with the typical subwatersheds and using the weighted precipitation excess value for that watershed, a hydrograph was developed to satisfy those requirements. This did not require a great deal of extrapolation inasmuch as the watersheds

were some 35 acres in size and the typical subwatersheds averaged 75-100 acres in size.

d. Distribution graphs were prepared for all local floods, ranging from 1,000 to 22,000 c.f.s., recorded near Fountain and Pueblo, see figure 2. Isohyetal maps of hourly rainfall from several recording gages located storm paths and the approximate areal extent of rainfall rates in excess of infiltration. These storm areas were verified by comparing the measured volume of runoff with the precipitation excess as determined by known rainfall and infiltration rates. The time between the centers of rainfall excess and the flood hydrograph, when corrected for the transit time of channel flow from the storm area to the stream gage, determined the lag interval. The velocity of channel flow was known from rating measurements by the U. S. Geological Survey and by comparing several flood hydrographs observed at both gages on the stream, (fig. 3). A summation graph (S-curve) of all distribution graphs was computed by dividing each hydrograph by the lag time as shown in figure 4. The concentration time for these local floods was associated with the storm areas shown by figure 5. Extremes of this relation were verified by hydrographs from small watersheds gaged by the SCS in the vicinity. By use of figures 4 and 5, a flood hydrograph can be computed for any typical tributary of Fountain River.

e. In order to determine the characteristics of typical small detention dams adaptable to this area, an examination was made

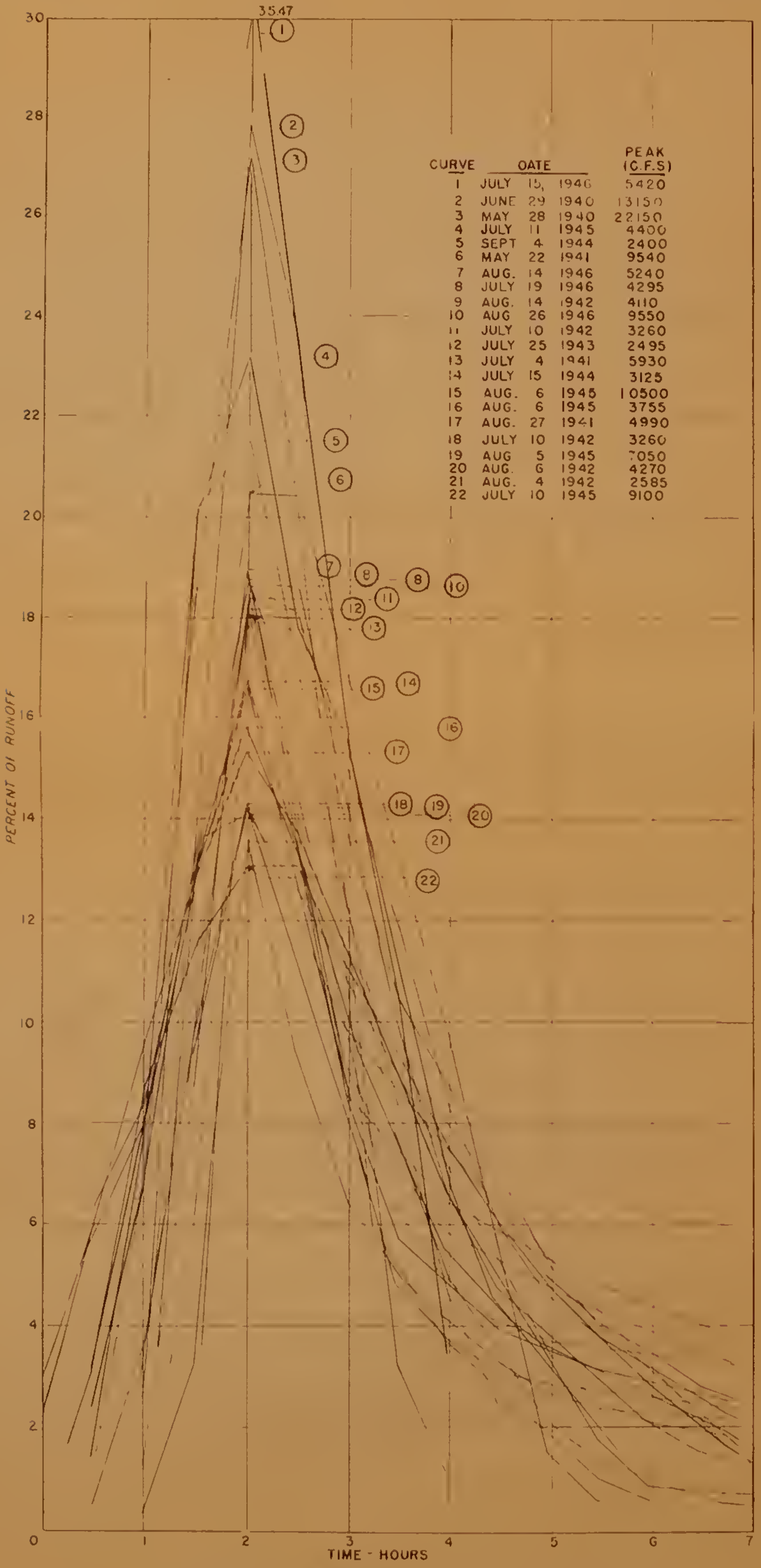


FIGURE 2 — DISTRIBUTION GRAPH

FOUNTAIN RIVER WATERSHED COLORADO

NEAR FOUNTAIN

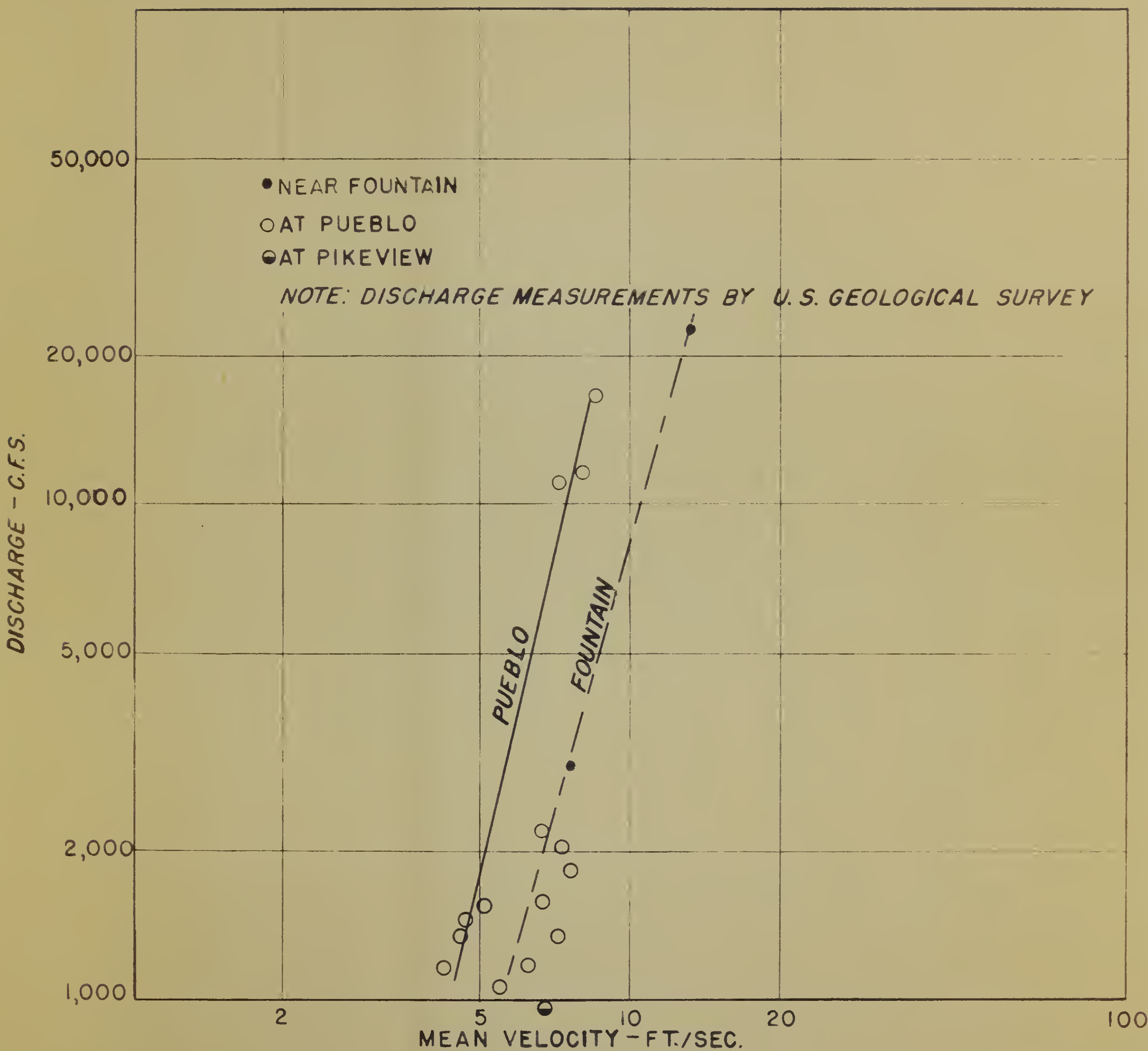


FIGURE 3 VELOCITY VS DISCHARGE

FOUNTAIN RIVER WATERSHED COLORADO 1940-46

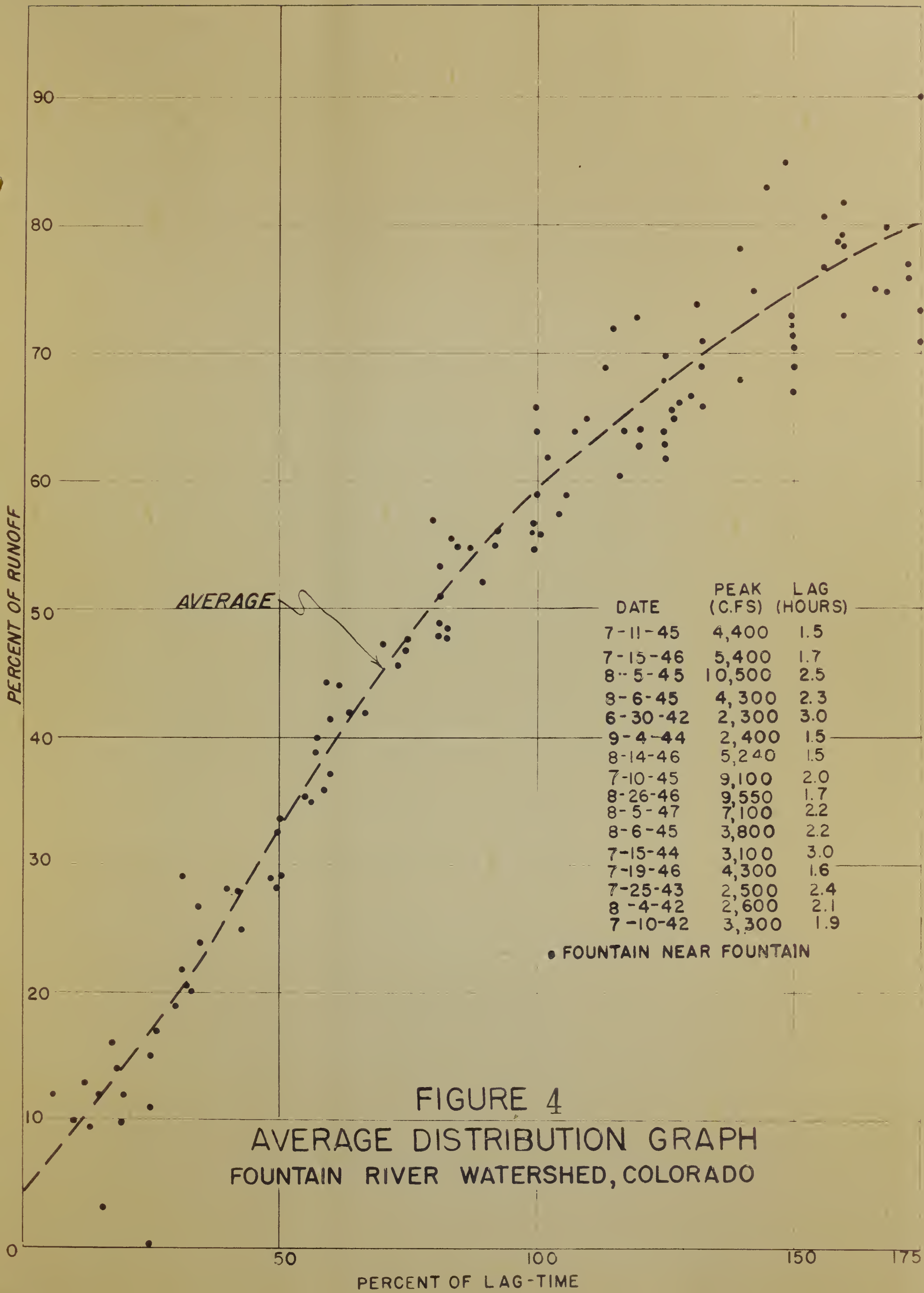


FIGURE 4

AVERAGE DISTRIBUTION GRAPH

FOUNTAIN RIVER WATERSHED, COLORADO

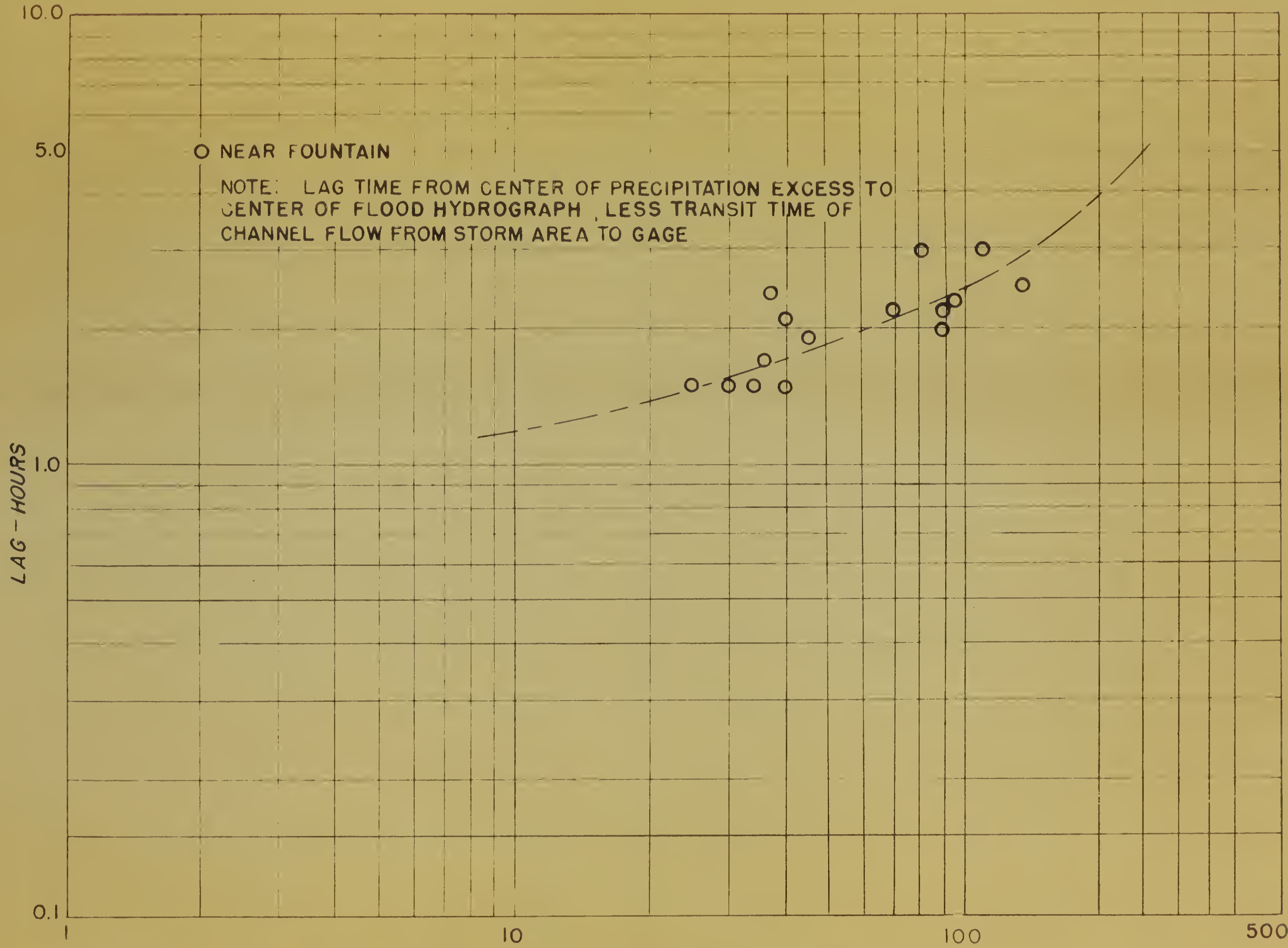


FIGURE 5 LAG VS AREA

FOUNTAIN RIVER WATERSHED COLORADO
1940-1946

of structures in the field and of plans prepared by local Soil Conservation Service offices. A number of topographic maps of dams constructed on similar watersheds in the vicinity were planimetered and a typical depth-volume curve developed. A typical depth-discharge curve was developed for the spillway, using spillway dimensions adaptable to the topography and spillway flow criteria as outlined by the Colorado State Engineer.

SEDIMENTATION

56. Public agencies have investigated various phases of the sedimentation characteristics of Fountain River. Basic data and analysis of these investigations were made available to the flood control survey party. Existing data were supplemented by field examinations and surveys.

57. The U. S. Corps of Engineers has been conducting a suspended load sampling program on the Upper Arkansas River since 1938. In technical cooperation with the Soil Conservation Service, the Corps is also conducting regular sedimentation surveys of John Martin Reservoir.

58. The watershed physical data collected by the survey party were used in identifying sediment source areas. Channel sedimentation studies included surveying eleven ranges on the Upper Arkansas River between Pueblo and John Martin Reservoir and two on Fountain River between Pueblo and Fountain. The relationship between bank cutting and sedimentation was studied on eight representative 1-mile reaches

of Fountain River channel and two sample reaches, each $1\frac{1}{2}$ miles long, on Monument Creek.

CHARACTERISTICS OF THE WATERSHED

CLIMATE

59. The great differences of elevation and physiography produce a wide range of climatic conditions. Maximum summer temperatures often reach 100°F. at elevations below 5,000 feet but rarely reach more than 80° to 90°F. at higher elevations. Occasional cold waves produce low temperatures which usually vary between 0°F. and -10°F. Although low temperatures are much more common at high altitudes, there is little difference between the extreme lows at different elevations. The minimum temperature of -27°F. for the area has been recorded at both Pueblo and Colorado Springs. Average annual temperatures for significant points are 51.9°F. at Pueblo, 47.4°F. at Colorado Springs, and 35.6°F. at Lake Moraine. (See table 1).

60. The watershed is not usually subject to severe freezing of the ground. At elevations of 6,500 feet and above, frost may extend to depths in excess of 1 to 2 feet for a period of about 2 months. Below 6,000 feet the ground is rarely frozen except during cold waves and then only to relatively shallow depths and for short periods of time. Frozen ground is not an important factor in the flood problem except in local areas where rapid snowmelt may result in the erosion and rilling of small areas.

61. The average relative humidity in the vicinity of the mountain front is about 50 percent, which is 15 to 20 percent less than in the lower Arkansas Valley. Wind movement is lowest near the mountain

Table 1. Climatic data for stations in Fountain River Watershed.

Month	Pueblo						Colorado Springs	
	Av. temp.	Humidity (percent)	Sunshine		Days with .01 or more precip.	Wind movement Av. hr. velocity	Av. temp.	Days with .01 or more precip.
			Av. hours	Percent possible				
January	31.1	57	232	76	4	8.0	28.4	3.1
February	33.6	56	226	74	5	8.5	30.1	4.1
March	41.2	50	269	72	6	9.1	37.4	5.9
April	50.2	49	275	69	6	9.3	45.5	7.2
May	59.5	51	310	71	8	8.8	54.1	10.0
June	69.5	47	339	77	7	8.3	63.7	8.3
July	74.7	51	334	75	9	7.9	68.4	11.7
August	73.2	54	314	74	8	7.3	67.0	11.4
September	65.0	50	388	77	5	7.4	59.9	6.1
October	52.8	50	262	76	4	7.4	49.3	3.9
November	40.5	54	227	75	3	7.4	38.5	3.0
December	31.8	59	215	73	4	7.4	30.9	3.1
Average annual	51.8	52	274	74	68	8.1	47.8	77.8
Length of record (years)	57	57	46	46	57	57	66	66

base but increases materially on the plains to the east where winds of sufficient velocity to cause erosion sometimes occur during the spring months. Along the mountain front and in the mountainous section, systems of mountain and valley winds are sufficiently active to materially influence local meteorological conditions.

62. The lengths of frost-free periods or growing seasons which indicate the broad range of climatic conditions vary from less than 60 days in the vicinity of Pikes Peak to 160 days at Pueblo. In the mountainous area, the season varies from less than 60 to about 100 days and on the plains from 100 to 160 days. Some general climatic data for Pueblo, Colorado Springs, and Lake Moraine are shown in table 1 (11).

PRECIPITATION

63. Total annual precipitation varies from 11 inches in the southern end of the watershed to about 25 inches in the mountains, reaching a maximum of 29.55 inches at Pikes Peak (figs. 6, 7, 8, and 9). The amount of precipitation varies with elevation to a high degree and the seasonal distribution to a lesser degree. Seasonal (April-September) rainfall amounts to 65 to 70 percent of the total precipitation for the higher elevations and 80 to 85 percent for the lower elevations. Most of the precipitation falling between October and March is in the form of snow. The maximum, minimum, and average monthly precipitation for Pueblo, Colorado Springs, Monument, and Lake Moraine are shown in table 2.

64. Average annual snowfall varies from 26.7 inches at Pueblo to 146.3 inches at Lake Moraine. At the lower elevations, snow cover

normally melts within a short period after each fall without contributing to the flood hazard. At the highest elevations, a general seasonal snow cover persists, however, snowmelt is relatively slow and quite uniform so that normally no major flood flows result. Nevertheless, some washing and rilling of local areas is caused by snowmelt.

STORM CHARACTERISTICS

Source and Seasonal Occurrence

65. Moist air masses originating in the Gulf of Mexico-Carribean area are the primary sources of precipitation in eastern Colorado. During the winter months, these air masses seldom invade the high plains and the location of this area with respect to the many mountain barriers westward is such that Pacific Ocean air masses--particularly active during winter--brings in very little moisture. In addition, the excessive temperature differentials necessary to the development of certain storm types are not characteristic of this season. As summer approaches, however, Gulf air masses become increasingly active, moving into the area from the south and southeast and land surfaces become progressively warmer. Inasmuch as the presence of quantities of warm, moist air and sharp temperature contrasts are necessary to the production of flood-producing rainfall, the likelihood of occurrence of such storms becomes increasingly greater as summer is approached. The probability of occurrence of heavy rainfall is greatest during the months of July, August, and September.

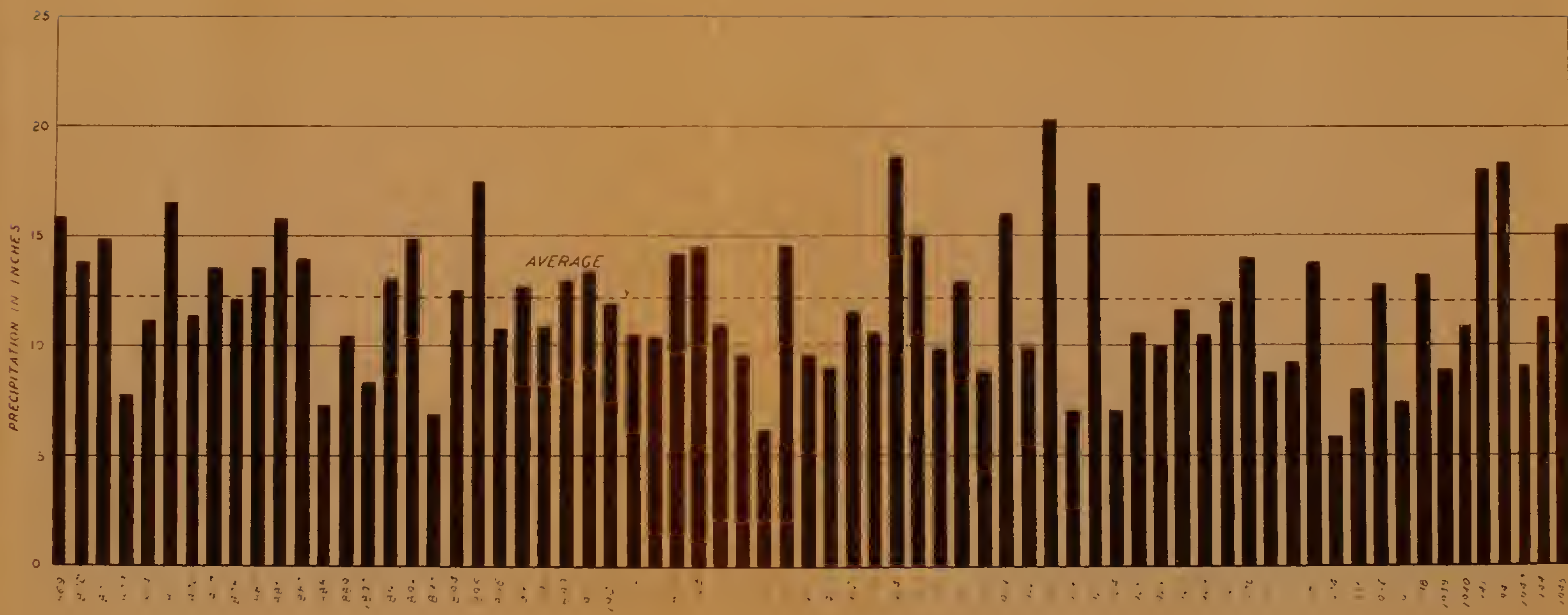


FIGURE 6
ANNUAL PRECIPITATION AT PUEBLO COLORADO
FOUNTAIN RIVER WATERSHED

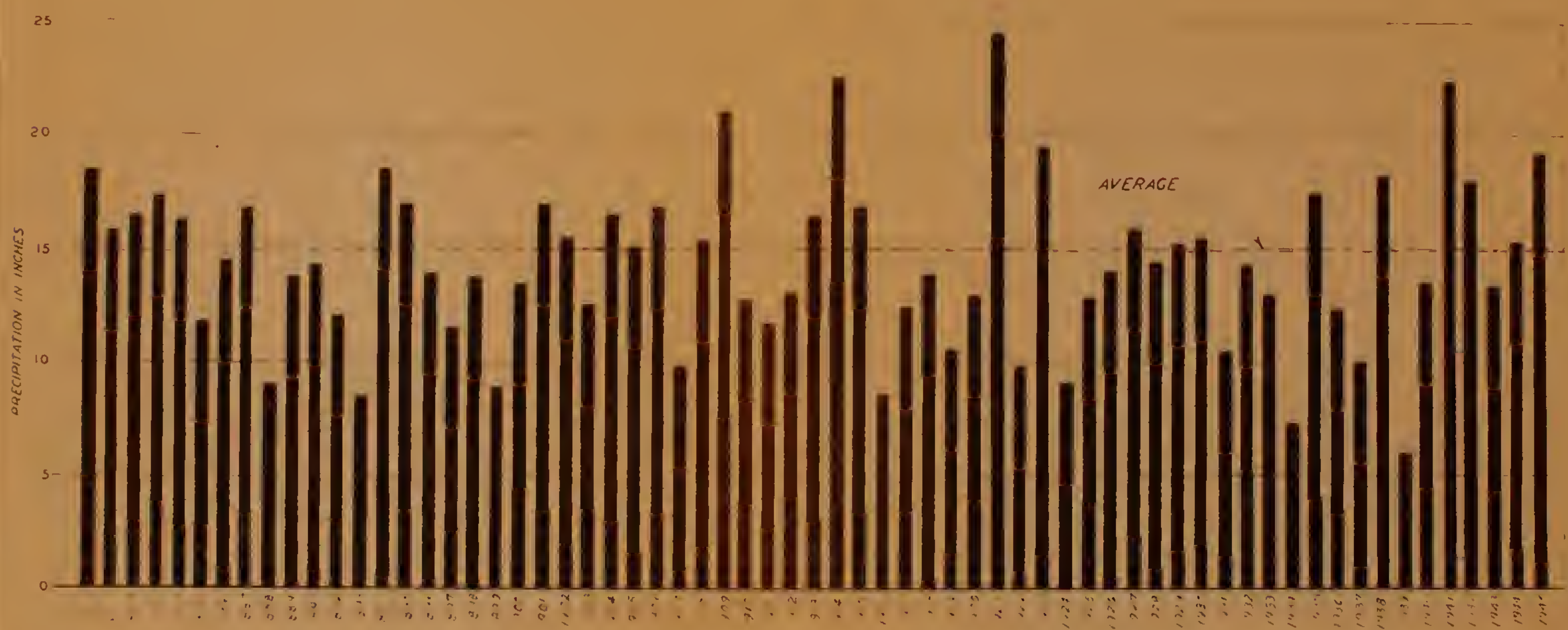


FIGURE 1

ANNUAL PRECIPITATION AT COLORADO SPRINGS, COLORADO

FOUNTAIN RIVER WATERSHED

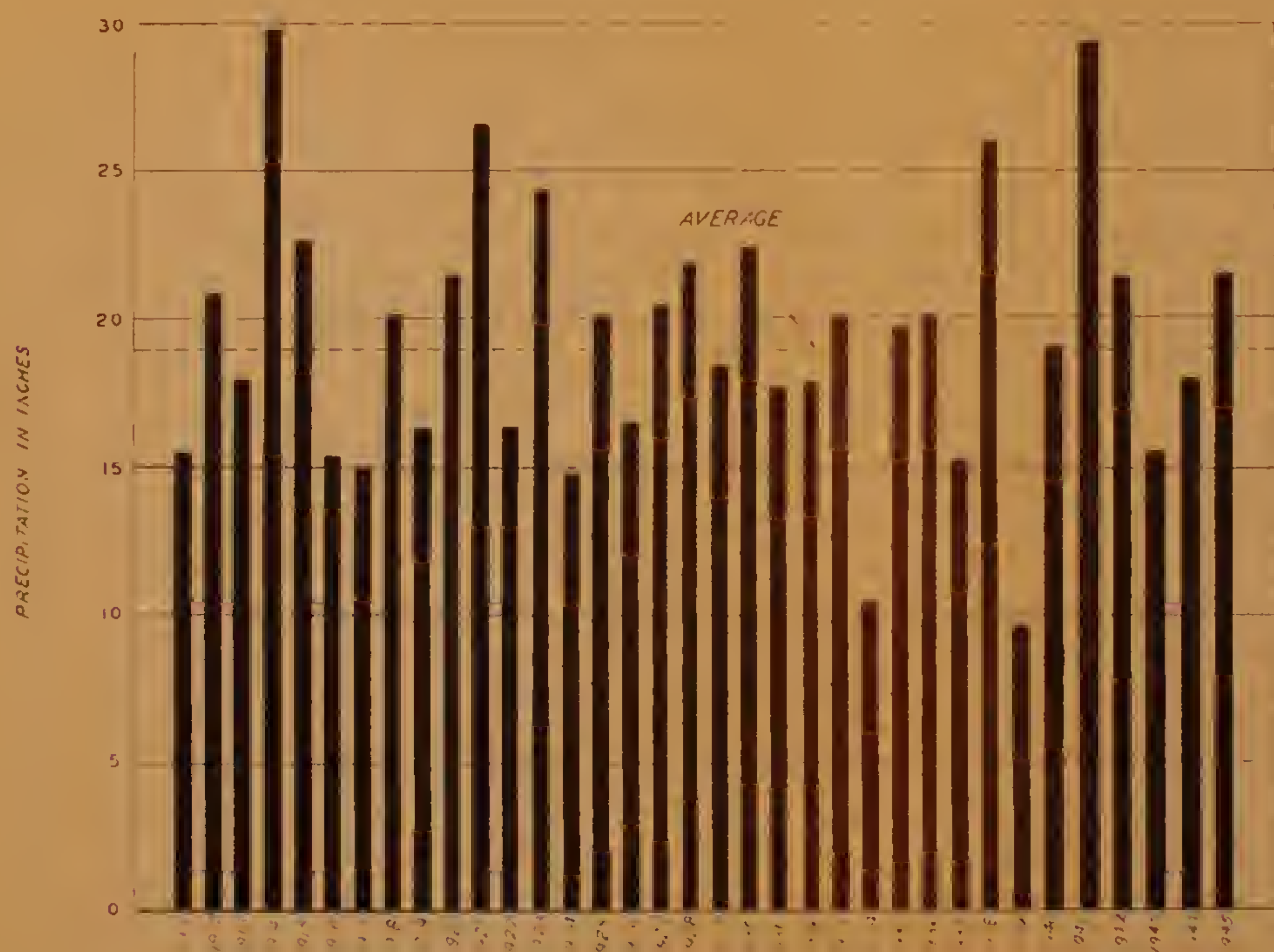


FIGURE 8

ANNUAL PRECIPITATION AT MONUMENT, COLORADO

FOUNTAIN RIVER WATERSHED

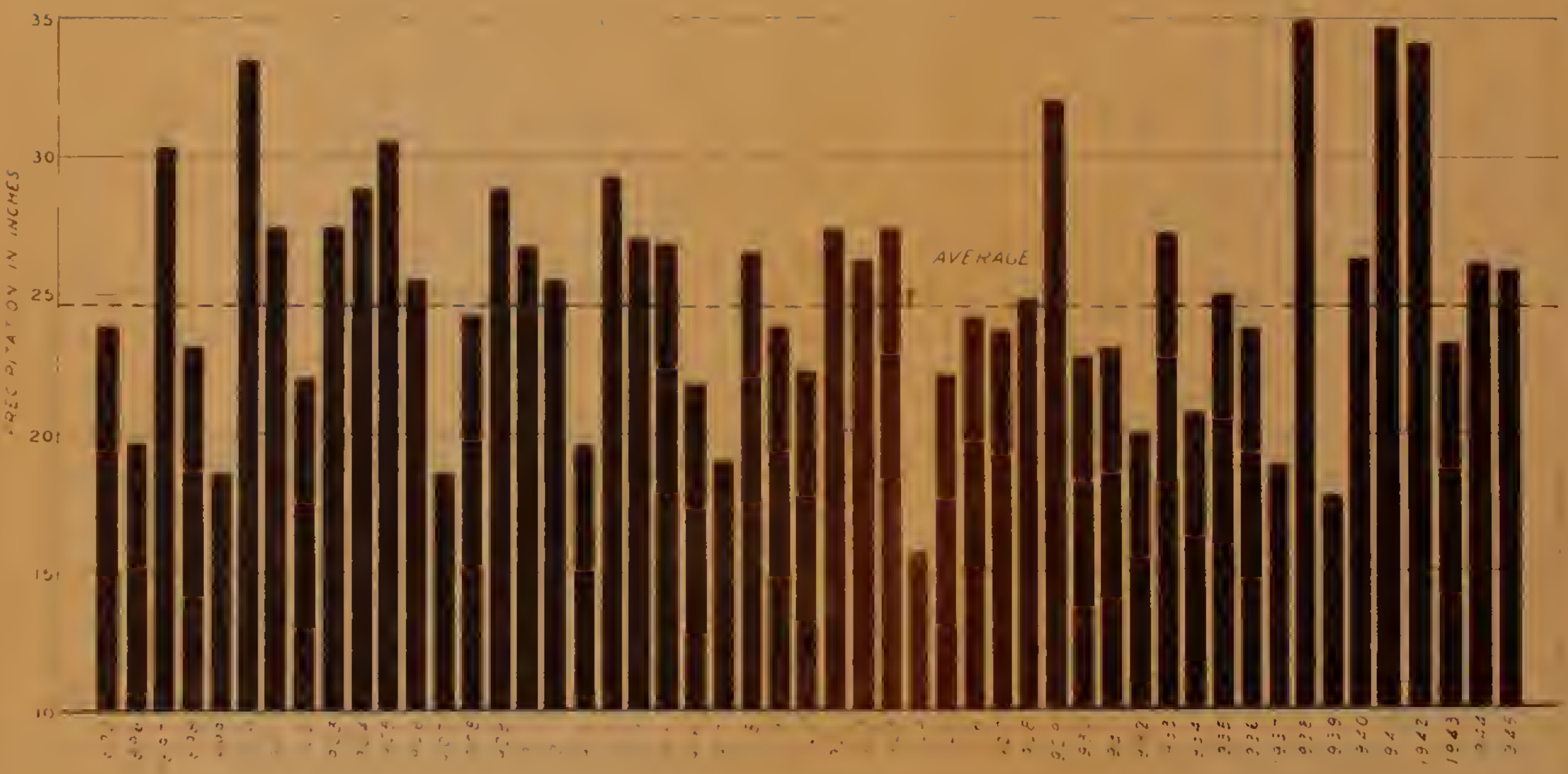


FIGURE 9
ANNUAL PRECIPITATION AT LAKE MORAINE, COLORADO
FOUNTAIN RIVER WATERSHED

Table 2. Maximum, minimum and mean precipitation, Fountain River Watershed.

Station	Period of record		Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual Year	Annual Amt.
Pueblo	1869	Max.	1.30	2.30	3.06	11.92	4.40	7.14	6.72	4.65	3.93	2.75	6.90	1.35	1921	20.28
	to	Min.	0.00	T	0.01	0.00	T	0.00	0.13	T	T	0.00	0.00	T	1934	5.78
	1945	Mean	0.31	0.47	0.59	1.31	1.60	1.36	1.96	1.82	0.75	0.66	0.36	0.50		11.69
Colorado Springs	1872	Max.	0.95	1.89	3.03	6.78	8.10	5.12	6.59	7.09	4.63	3.45	2.30	2.54	1921	24.55
	to	Min.	0.00	0.00	T	0.02	0.09	0.20	0.30	0.19	0.02	T	0.00	T	1939	6.07
	1945	Mean	0.21	0.38	0.72	1.60	2.22	1.79	2.81	2.30	1.13	0.58	0.33	0.30		14.37
Monument	1911	Max.	1.27	2.18	3.63	5.91	8.63	4.65	8.10	7.38	5.25	4.37	2.39	4.21	1914	29.68
	to	Min.	0.00	T	0.24	0.66	0.54	0.26	1.03	1.02	0.10	0.00	0.13	0.04	1939	9.67
	1945	Mean	0.44	0.76	1.42	2.92	2.51	1.72	3.04	2.77	1.42	1.08	0.79	0.73		19.60
Lake Moraine	1895	Max.	1.84	3.45	3.95	16.55	6.98	7.48	8.22	8.99	6.23	5.09	3.38	6.49	1938	34.91
	to	Min.	T	0.06	0.48	0.69	0.52	0.10	1.26	0.87	0.13	0.05	T	0.02	1924	15.75
	1945	Mean	0.67	0.95	1.80	3.19	2.82	2.53	4.25	3.81	1.73	1.49	0.84	0.80		24.88

Storm Types

General-summer

66. During invasions of moist Gulf air, heavy precipitation may occur over large areas of eastern Colorado. These storms may result from a variety of meteorological reactions among which are:

a. Warm moist air makes contact with cooler air along "fronts" or planes of contact. If a front remains more or less stationary in one location heavy and sustained rainfall may result.

b. Moist air masses come into contact with land forms that force them upward with resultant cooling and condensation of moisture. As long as the directional movement remains constant and moist air is available, precipitation is likely to continue.

67. A characteristic of this storm type is heavy sustained precipitation of long duration. Insofar as the storm area as a whole is concerned, intensities are not likely to be as high as in other storm types. Often, however, there are located within the storm area one or more centers of intensity where rates and amounts of rainfall exceed those in the surrounding territory. It is this type of storm that ordinarily produces the maximum floods from larger watersheds.

68. The storm of May 30, 1935, offers an excellent example of the general storm type (fig. 10). This storm was associated with a general cyclonic disturbance caused by a high pressure area over Minnesota and the Great Lakes and a low pressure area over southwestern Colorado and Arizona. The frontal area extended northeastward from

the mountain front approximately along the Arkansas and South Platte Divide. Heavy rainfall occurred during the afternoon and night of the 30th. Several intense local centers of precipitation were reported along the general frontal area. One such center was just south of the Arkansas-South Platte Divide from Cherry Creek watershed and another approximately 8 miles east of the eastern boundary of the watershed. Although no Weather Bureau records were available in or near the storm centers, unofficial reports placed the rainfall during the storm period as high as 24". This storm caused the highest known flows from several tributaries of the South Platte River east of Cherry Creek, the Republican River in eastern Colorado, and Monument Creek in Colorado Springs.

Convective

69. The presence of moist air in a given locality and heat differentials are the primary requisites to the development of a convective type storm. They may occur without regard to frontal activity or orographic influences. During the summer months intense heating of moist air at or near the ground surface results in convectional instability, i.e., moist air at a given location is warmed to the extent that it moves upward with resultant cooling and condensation. This type, commonly termed the "thunderstorm," often produces intensities much higher than those characteristic of the general storm type. Ordinarily, however, they cover limited areas and are of short duration (fig. 10). Such storms are of importance only in the consideration of floods from small watersheds.

70. A storm which occurred 3 miles southwest of Pueblo, Colorado, on the afternoon of August 26, 1946, is an example of this type.

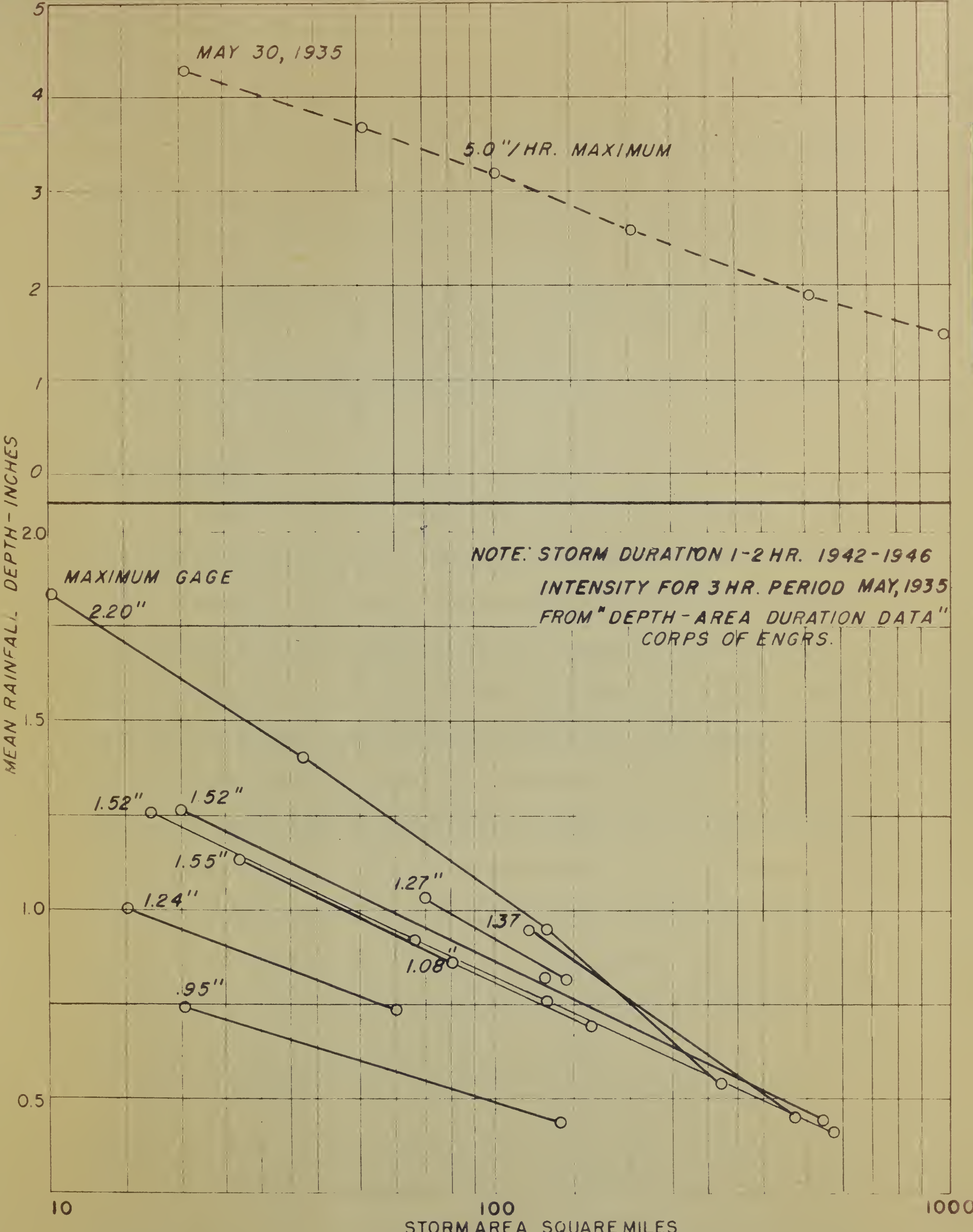


FIGURE 10 DEPTH VS AREA

FOUNTAIN RIVER WATERSHED COLORADO, 1942-46

Beginning abruptly with an intensity of 3.00 inches per hour for 10 minutes, the rainfall reached an intensity of 4.40 inches per hour for the next 15 minutes then receded in intensity until the cessation of rainfall at the end of 55 minutes. This storm totalled 2.30 inches in a period of 55 minutes and occurred at an average rate of 2.51 inches per hour. At Pueblo, only 3 miles away, the rainfall was negligible. On this date the maximum precipitation recorded at any other station in Colorado was 1.31 inches.

<u>Lift Convective</u>

71. A third storm type about which very little is known is that occurring in association with convective activity and which is accelerated by orographic influences. Undoubtedly the combination of these two phenomena at times results in storms of greater magnitude than would ordinarily occur had either factor not been contributing. Such storms may be formed by convection in association with lifting, turning, or funneling of warm moist air by various land forms. The position of the Rocky Mountain barrier as it rises abruptly from the Great Plains in the path of westward or northwestward moving air masses often results in storms of much greater than ordinary proportions. These storms, as in the case of the purely convective type, are not necessarily associated with general storms--although such has often been the case--nor do they necessarily cover large areas.

72. An example of such a storm occurred in and near Manitou Springs, Colorado, on the afternoon of May 10, 1947. During the fore part of the afternoon a cumulo-nimbus or thunderhead type of cloud began to develop over the Rampart Range Mountains just north of Manitou

Springs. The location of this cloud formation and its subsequent development clearly showed that not only convective activity but also orographic influence was a contributing factor. A rain gage at Manitou recorded heavy rainfall beginning at 2:15 p.m. with 3.30 inches falling during the next 2 hours and 20 minutes and 5.22 inches occurring in 6 hours and 40 minutes. Isohyetals of the storm period plotted from rain gage records and unofficial measurements in the vicinity indicated that precipitation in the storm center--located on the Rampart Range--was greater than that at Manitou Springs. It is likely that at least 6 to 7 inches of rain fell at this location. Such storms are believed to be characteristic to the frontal portions of the Rocky Mountain Range.

General-winter

73. During winter months when moist air, either of Gulf or Pacific origin, is present in eastern Colorado, one or a combination of various meteorological reactions may cause precipitation. Ordinarily, however, insufficient moisture is available for the production of intense storms and the heat differentials necessary to the development of such storms are not in evidence. As a result, the storms are characterized by rains, usually general in extent but of very low intensity, or by snowfall. Floods of sufficient magnitude to cause extensive damage are virtually unknown during this season of the year.

CHANNEL AND STREAM FLOW CHARACTERISTICS

Description of Stream Channel

74. Stream channel gradients vary greatly because of the typical plains and mountain drainages involved. The main channel from Colorado Springs to the Arkansas River has a relatively uniform slope averaging 25 feet per mile. Monument Creek ranges in slope from an average of 40 feet per mile for the reach between Colorado Springs to Monument to more than 500 feet per mile in the mountain reaches. Condensed profiles are shown in figure 11.

75. Northern plains streams such as Cottonwood, Pine, and Kettle Creeks, which rise in the Black Forest, have channel gradients ranging from 45 to 335 feet per mile. Jimmy Camp and Sand Creeks in the southern plains have slopes ranging from 35 to 70 feet per mile, respectively.

76. Channels of the plains area have bottoms of loose sand or gravel and practically vertical sides through most reaches. Vegetation within these channels rarely achieves sufficient growth to affect flow conditions materially. The typical cross section for the plains channels is approximately rectangular, with the bottom width several times greater than the depth.

77. Mountain stream channels with their steep gradients have relatively small cross sections which are somewhat V-shaped. Channel banks frequently are merely extensions of upland slopes. In most cases the channel capacity is capable of carrying the flow produced by the area which it drains.

Average Seasonal and Annual Runoff

78. Stream gaging records on the Fountain River at Fountain and Pueblo are summarized in table 3. The record is short but contains at least one period during which the runoff was exceptionally high; for example, the monthly discharge in April 1942 at Fountain was more than five times as much as that recorded during any other April of the 7 years of record. Runoff records from the small mountain tributaries of the watershed have been maintained for many years by the Colorado Springs Water Department; these long-time averages are more reliable than the short records previously mentioned. Table 3 also shows the runoff from Bear Creek, a mountain tributary near Colorado Springs.

79. The average annual runoff from high elevations of the watershed is much greater than that from the plains area. For example, the runoff from Bear Creek has averaged 1,411 acre feet annually from a 7.56 square mile area, or 187 acre feet per square mile, while the inflow between Fountain and Pueblo, wholly from the plains areas, has averaged 11,158 acre feet from 256 square miles, or 15 acre feet per square mile. Considering diversions for irrigation between these two stations, which might double the inflow, the difference between runoff contribution of the mountains and plains areas is quite marked. The summer flow of Fountain River is sustained almost wholly by the mountain streams. The importance of the mountains as a dependable source of water is brought out by the fact that most irrigation and municipal culinary water flows from the western tributaries of the river. Practically none of the eastern plains tributaries are perennial.

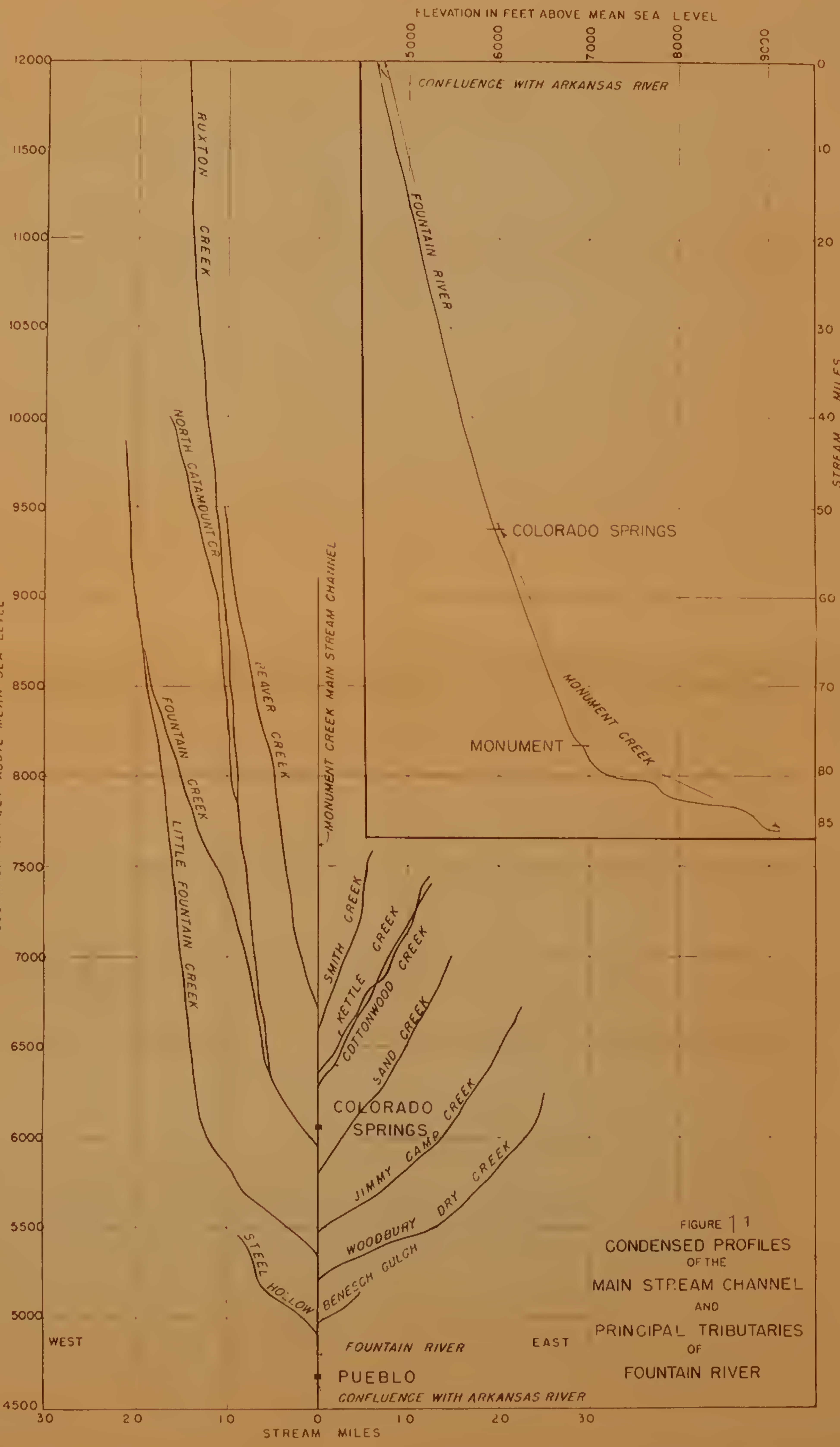


FIGURE 11
CONDENSED PROFILES
OF THE
MAIN STREAM CHANNEL
AND
PRINCIPAL TRIBUTARIES
OF
FOUNTAIN RIVER

Table 3. Average monthly and annual runoff, Fountain River Watershed.

	Years of record	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
Fountain at Pueblo - 932 square miles														
	1923	652	1,230	1,050	293	2,500	9,100	23,900	13,000	8,630	11,300	10,500	5,470	87,625
	1924	2,270	4,320	4,460	5,880	11,400	12,900	117	478	60	470	433	1,570	44,358
	1942	3,480	3,610	3,800	33,540	41,650	17,020	6,320	13,130	3,830	5,390	6,840	5,610	144,220
	1943	3,250	3,980	2,280	503	2,220	135	61	223	63	64	770	2,160	15,709
	1944	1,970	1,830	1,880	7,090	23,640	7,660	3,910	2,350	1,200	174	540	1,610	53,854
	1945	1,910	2,560	1,230	1,290	592	156	5,150	17,160	177	920	1,210	3,030	35,385
Average		2,255	2,922	2,450	8,099	13,667	7,829	6,576	7,724	2,327	3,053	3,382	3,242	63,526
Acre ft. per square mile		2.4	3.1	2.6	8.7	14.7	8.4	7.1	8.3	2.5	3.3	3.6	3.5	68.2
Fountain near Fountain - 676 square miles														
	1939	1,630	2,630	3,630	5,450	1,510	406	271	638	78	232	595	492	17,562
	1940	1,540	1,730	773	956	5,950	1,230	3,880	299	1,330	1,000	874	484	20,046
	1941	762	337	393	6,810	14,880	7,030	3,510	3,650	2,170	5,950	7,980	3,510	56,982
	1942	2,060	2,810	4,840	35,120	37,040	19,590	8,030	7,710	2,520	4,630	5,690	3,540	133,580
	1943	4,340	3,010	3,430	1,320	3,030	1,190	1,940	2,550	785	565	1,440	2,260	25,860
	1944	1,880	1,530	1,230	6,430	28,800	10,220	7,180	2,090	1,380	1,270	1,320	1,680	65,010
	1945	1,190	1,530	1,010	1,140	1,380	1,010	3,950	29,280	1,220	1,970	1,820	2,020	47,520
Average		1,915	1,940	2,187	8,175	13,227	5,811	4,109	6,603	1,355	2,231	2,817	1,998	52,368
Acre ft. per square mile		2.8	2.9	3.2	12.1	19.6	8.6	6.1	9.8	2.0	3.3	4.2	3.0	77.6
Bear Creek near Colorado Springs - 7.56 square miles														
(Av. 1919-45)		61	53	69	121	229	206	144	155	115	99	86	73	1,411
Acre ft. per square mile		8.1	7.0	9.1	16.0	30.3	27.2	19.0	20.5	15.2	13.1	11.4	9.7	186.6

80. Seasonal (April-September) runoff from the watershed accounts for a large part of the annual flow. During the period of record, 73 percent of the total at Pueblo, 75 percent of the total at Fountain, and 67 percent of the total from Bear Creek occurred during these 6 months. Due to the characteristic extremes in precipitation that occur in the watershed, runoff during individual months may vary widely. During August 1940, the measured discharge at Fountain totaled 299 acre feet, while during August 1945, the total was 29,280 acre feet, or 100 times as great.

81. Mean daily discharges vary from zero at times during the summer months to 1,880 c.f.s. on August 21, 1945, at Fountain. The high discharges of storm runoff, however, are seldom over a few hours duration due to the flashy nature of storm runoff. Discharges from snowmelt may not result in such high peaks, but may produce greater quantities of water.

Flood Flows

82. The watershed of Fountain River may be divided into two distinct subareas, considering flood-producing characteristics: the mountains and the plains. The mountainous portions of the area produce much more water than do the plains; insofar as the production of floods is concerned, the reverse is true. A combination of good vegetal cover and characteristically lower rainfall intensities minimize the probability of frequent main stem major floods occurring from the mountains. In certain localized areas, however, and particularly where stream channels are constricted, runoff from the mountains has caused extensive damage.

The magnitude of such floods, although they are damaging, is still much less than that of floods occurring from the plains.

83. The heavy general and convective type storms frequently occur over the plains area of Fountain River watershed. This part of the area is poorly vegetated; as a result, floods of considerable magnitude occur with high frequency.

84. Floods are produced by two distinct storm types in the lower elevations of the watershed: The general rain and the convective type. Heavy general rain falling on large portions of the basin is characterized by high discharges in the main stem. Although excessive rates of runoff may occur from small tributaries located near the storm center, it is not necessary that all subareas produce maximum peaks in order for flood stages to develop in the principal waterway. The cumulative effect of even moderate runoff rates from a number of tributaries may result in a flood of damaging proportions downstream.

85. Floods also result from either the convective or lift-convective storm type. The limited extent and duration of these storms ordinarily does not produce damaging floods along the main stem except in isolated stretches of the river. The volume of flood runoff from this storm type is not ordinarily sufficient to sustain damaging peaks for any length of time. The flood crest is quickly flattened by channel storage and often little notice is taken of the runoff at points only a few miles downstream. On small tributaries, however, the "flash-flood" type of runoff is of utmost importance. Whereas floods in the main stem, as the result of general storms are rather infrequent, the short but intense summer floods on minor tributaries are virtually a

a yearly occurrence. Often the magnitude of this type of flood is much greater from small watersheds than that which might result from the general type of storm. There are no stream gaging stations on such subareas, however, and it is difficult to determine the frequency of occurrence of the flash floods on a watershed basis. Point rainfall studies provide the best indication of flood frequencies of any given location.

Flood History

General

86. Little information is available concerning the flood history of watersheds tributary to Fountain River. A history of flood flows as they are believed to have occurred at Pueblo, Colorado Springs, and Manitou Springs, however, has been compiled from various sources including newspaper reports, verbal accounts, and a report compiled by the Corps of Engineers (1). During the period 1864-1947, six floods are reported to have occurred at Pueblo, seven at Colorado Springs, and six at Manitou Springs. The nature of those floods was as follows:

Flood of June 10, 1864

87. This flood originated in Monument Creek and caused the loss of 13 lives. No rainfall data are available, but it has been estimated that the peak discharge at Colorado Springs was about 40,000 cubic feet per second. The estimated peak discharge at Pueblo was 45,000 c.f.s.

Flood of 1880 (no information except "summer")

88. A severe flood from Williams Canyon caused considerable damage and the loss of one life in Manitou Springs. No information is available as to the rainfall and runoff.

Flood of July 1882

89. A damaging flood again occurred from Williams Canyon at Manitou Springs. No other information is available.

Flood of July 25, 1885

90. This flood was caused by an isolated convective type storm centering over the Templeton Gap area east of Colorado Springs. One life was lost as the result of a reported maximum discharge in Shooks Run of 6,120 c.f.s.

Flood of August 2, 1886

91. This flood was caused by excessive rainfall occurring on the Monument Creek watershed. Damages at Colorado Springs was caused both by flooding of Monument Creek and Shooks Run. The estimated peak discharge from Monument Creek was 40,000 c.f.s. and from Shooks Run 4,000 c.f.s.

Flood of July 27, 1893

92. This flood apparently originated on the Fountain River watershed below Colorado Springs as no mention is made of damages in that vicinity. A peak discharge of 40,000 c.f.s. was reported to have occurred at Pueblo.

Flood of May 30, 1894

93. Another flood of similar origin and size as the July 27, 1893, flood was reported to have occurred on this date.

Flood of July 1897

94. A flood of damaging proportions occurred from Williams Canyon at Manitou Springs during July (date unknown). No other information is available.

Flood of 1897 (no information except "summer")

95. Williams Canyon was reported to have again flooded a portion of Manitou Springs. The flood was described as "severe" but no other information is available.

Flood of August 5, 1902

96. High runoff from Fountain River through Manitou Springs apparently caused considerable damage to the municipality. The storm was reported to have centered in the vicinity of Green Mountain Falls.

Flood of August 7, 1904

97. Apparently a localized convective storm caused a flood from a small tributary to Fountain River named Edens Gulch. The estimated maximum discharge was 9,640 cubic feet per second. The flood apparently was of importance locally inasmuch as no damage was reported elsewhere. The flood runoff, however, caused a train wreck which resulted in the loss of more than 100 lives.

Flood of June 3-4, 1921

98. This flood was the greatest reported in the flood history of Fountain River at Pueblo. Although excessive rainfall occurred over the greater part of the basin, the heaviest precipitation apparently occurred below Colorado Springs. The flood crest, estimated at from 35,000 to 50,000 c.f.s. reached Pueblo only a few hours after the crest of a flood on the Arkansas River, which reached an estimated peak discharge of 103,000 c.f.s. At Pueblo the arrival of Fountain River flow undoubtedly increased the damages which would have been caused by flood waters of the Arkansas River alone.

Flood of June 5, 1921

99. Heavy, continuous rains falling on good snow cover resulted in one of the most damaging floods in the history of Manitou Springs. Flood flows were reported from Fountain Creek and Williams and Ruxton Canyons.

Flood of May 27, 1922

100. A localized convective type storm occurring over the Templeton Gap area resulted in an estimated flow of 6,120 c.f.s. in Shooks Run. Extensive damages were reported to have been sustained in the eastern section of Colorado Springs.

Flood of July 29-30, 1932

101. This flood resulted from excessive rainfall in the Templeton Gap area. A maximum discharge of 9,700 c.f.s. was estimated at Templeton Gap, which was greater than any other flood reported from that area and the resulting damage in Colorado Springs was high.

Flood of May 30-31, 1935

102. This flood was primarily caused by excessive rains occurring on the Monument Creek watershed above Colorado Springs. There were reports of as much as 7 and 8 inches of rainfall in 24 hours at certain points within the storm area. The resultant maximum discharge of the Monument at Colorado Springs was estimated at 50,000 c.f.s., the highest yet known to have occurred. The storm centered north of Colorado Springs, and no high discharges were reported from Shooks Run or from the Fountain above Colorado Springs. Flooding was general, however, throughout the lower Monument and the Fountain below Colorado Springs. The flood peak was materially reduced between Colorado Springs and Pueblo where the estimated maximum discharge was 25,000 c.f.s.

Flood of May 10, 1947

103. During the afternoon of May 10, 1947, a thunderstorm developed over the Rampart Range just north of Manitou Springs. The resulting precipitation was both heavy and sustained, totaling some 5 inches at the Manitou Springs power plant. Apparently the storm centered north of this point and undoubtedly the rainfall was greater at that location. No rainfall records, however, were available in the area of storm center. The resulting runoff from Fountain Creek and Williams Canyon inundated parts of Manitou Springs, caused loss of one life, and deposited large amounts of sediment and debris on streets, lawns, and in houses. This was one of the most damaging floods in the history of the municipality.

GEOLOGY AND GROUND WATER

Stratigraphy

General

104. The surface formations of the Fountain River watershed include rocks of both igneous and sedimentary origin. The principal igneous rock is a pre-Cambrian granite which outcrops in the mountains and occupies 24 percent of the drainage area. The sedimentary rocks, sandstone, limestone, shale, and arkose are exposed in the foothills
late
and on the plains and range in age from Cambrian to early Tertiary time. They cover 64 percent of the watershed. The remaining 12 percent contains unconsolidated deposits including glacial drift, mesa-capped gravels, terraced stream gravels, and other alluvium of Quaternary Age. (Map 3 and table 4) (14).

Pre-Cambrian

105. The pre-Cambrian granite rock is hard, dense, weathers slowly and has a low infiltration rate but its weathered product has a high infiltration rate.

Paleozoic

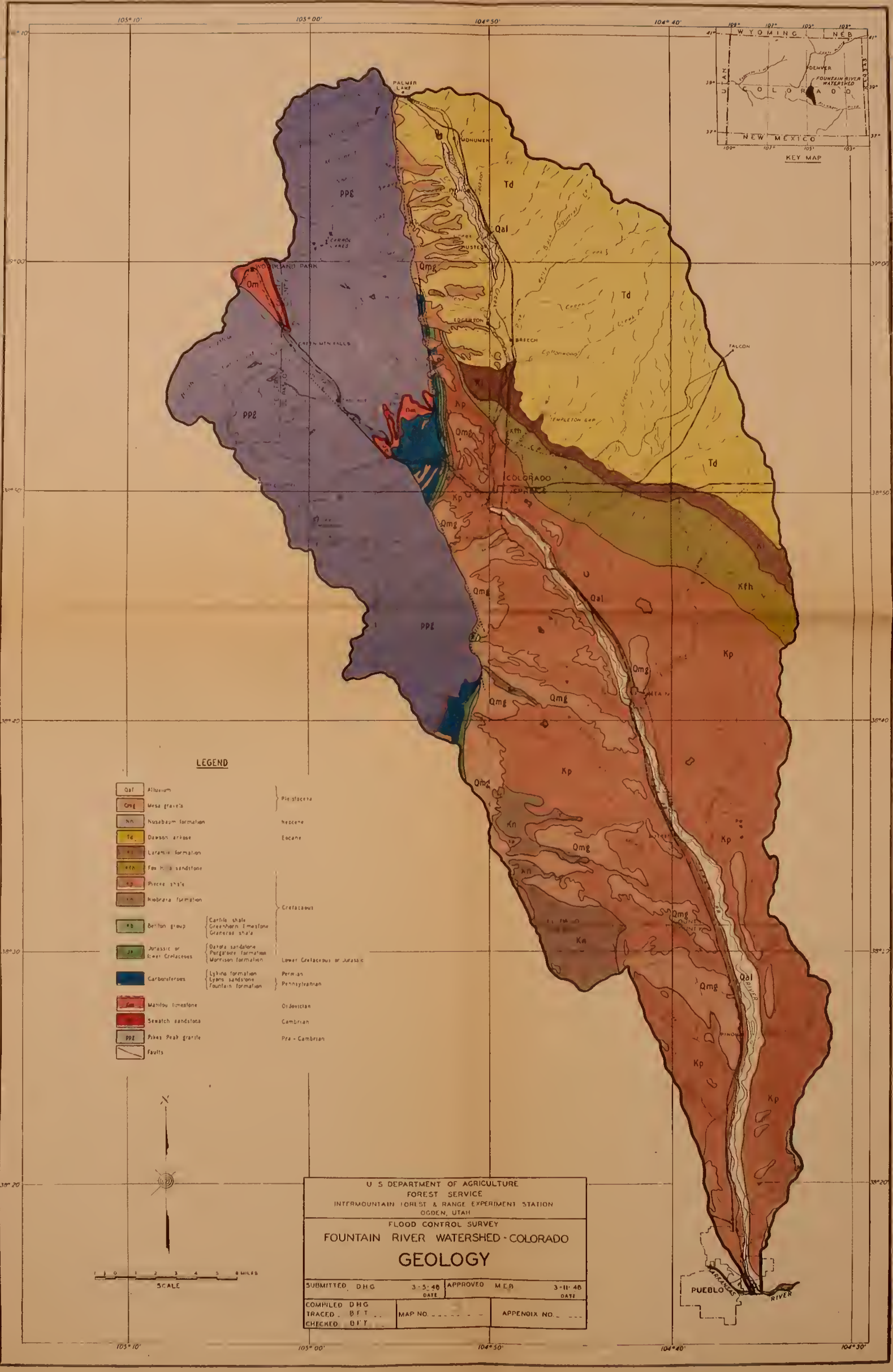
106. Steeply dipping Paleozoic rocks are exposed in small areas in the foothills and in the vicinity of Woodland Park. Although occupying only about 2 percent of the watershed, formations of this age include sandstones, shales, arkoses, conglomerates, and limestones, some of which produce easily eroded soils.

Mesozoic

107. Mesozoic rocks outcrop over 63 percent of the watershed. The Morrison, Purgatoire, Dakota, Graneros, Greenhorn, Carlile, and Niobrara formations outcrop in a very limited area and generally in narrow bands in the foothills.

108. The Pierre shale covers 32 percent of the drainage and constitutes the principal surface formation below Fountain village. Numerous sandy beds lie in the upper and middle portions, whereas the lower part contains considerable gypsum. Pierre shale is a soft rock, weathers rapidly, has a low infiltration rate and the weathered material is highly erodible.

109. The Fox Hills sandstone lies conformably on the Pierre shale and is overlain in uninterrupted sequence by the Laramie formation. The formation consists of a friable quartz sandstone containing mica. In the lower two-thirds the beds of sandstone are separated by layers of clay or shale. It is an important aquifer, especially in the upper part.



U S DEPARTMENT OF AGRICULTURE
FOREST SERVICE
INTERMOUNTAIN FOREST & RANGE EXPERIMENT STATION
OGDEN, UTAH
FLOOD CONTROL SURVEY
FOUNTAIN RIVER WATERSHED - COLORADO
GEOLOGY
SUBMITTED DHG 3-5-48 DATE
APPROVED MEB 3-11-48 DATE
COMPILED DHG
TRACED BFT
CHECKED BFT
MAP NO.
APPENDIX NO.
LEGEND
Qal Alluvium
Qmg Mesa gravels
Pleistocene
Nussbaum formation
Neocene
Td Dawson arkose
Eocene
Laramie formation
Fox Hills sandstone
Pierre shale
Niobrara formation
Cretaceous
Benton group
Carlile shale
Greenhorn limestone
Graneros shale
Jurassic or Lower Cretaceous
Dakota sandstone
Purgatoire formation
Morrison formation
Lower Cretaceous or Jurassic
Carboniferous
Lykins formation
Lyons sandstone
Fountain formation
Permian
Pennsylvanian
Manitou limestone
Ordovician
Sawatch sandstone
Cambrian
PPE Pikes Peak granite
Pre - Cambrian
Faults
SCALE
KEY MAP
WYOMING
NEB
UTAH
COLORADO
NEW MEXICO
DENVER
FOUNTAIN RIVER WATERSHED
PALMER LAKE
MONUMENT
WOODLAND PARK
COLORADO SPRINGS
FALCON
PUEBLO
ARKANSAS RIVER
105° 10'
105° 00'
104° 50'
104° 40'
104° 30'

Table 4. Columnar section of strata near Colorado Springs, Colorado.

Era	Geologic age	Formation & section symbol	Thickness	Portion of watershed	Description
			Feet	Percent	
CENOZOIC	Quaternary	Alluvium Qal	10-60	2.7	Unconsolidated silt, sand and gravel; occurs in flood plain deposits and terraces along principal streams.
		Mesa gravel Qmg	10-50	9.7	Coarse, roughly sorted gravel containing sandy layers; veneers the sloping tablelands extending eastward from the mountains.
	Tertiary 1/	Dawson arkose Td Andesitic member	1,000	21.1	Principally a soft, coarse to medium-textured arkosic sandstone; contains in the lower part a bed of andesitic sandstone underlain by carbonaceous clay, sandy shale, and conglomerate. Weathers to rolling hills, locally prominent bluffs.
MESOZOIC	Cretaceous	Laramie formation Kl	250-500	1.9	Shale with interbedded sandstone and massive basal sandstone beds containing shale and coal. Outcrop forms slopes, bluffs, and low ridges.
		Montana Group Fox Hills sandstone Kfh	600	4.9	Friable quartz sandstone, contains biotite and muscovite mica, and in the upper beds large concretions. Lower two-thirds of formation contains clay and is interlain with shale. Outcrops on slopes and in low bluffs.
		Pierre shale Kp	2,500	32.0	Lead gray shale; contains numerous sandy layers in the upper and middle portion, and horizons of iron-stained limestone concretions in the lower 500 feet. Weathers to smooth slopes and plains.

Table 4. (Continued)

Geologic age	Formation & section symbol	Thickness	Portion of watershed	Description
		Feet	Percent	
	Colorado Group Niobrara formation Kn	400-500		Upper two-thirds is finely laminated bluish black calcareous shale containing thin layers of gypsum. The lower one-third consists of interbedded limestone and shale with 50 feet of bluish-gray limestone at the base. The outcrop weathers to cuestas and low limestone hills.
	Carlile shale Kcr	60		Thin-bedded, black shale capped by 10 to 20 feet of fine-grained, yellow, calcareous sandstone.
	Greenhorn	50	0.1	Thin-bedded, light bluish gray limestone alternating with beds of shaly limestone and gray shale.
MESOZOIC Cretaceous	Graneros shale Kgs	175-220		Light gray to dark shale. Upper beds leached and rich in kaolin. A bed of sandstone near the middle, 4 ft. in thickness, resembles the Dakota S.S. The lower beds are fine-grained, purplish or slate-colored.
	Dakota sandstone Kd	100		Buff to gray, quartz sandstone, even-grained, cross-bedded, and ripple-marked. Formation contains 10 feet of interbedded shale and sandstone near middle, and pebble conglomerate at base.
	Purgatoire formation Kgc Kly	195-295	0.2	Upper portion consists of dark fractured gypsiferous shale containing a few sandy beds. (Glenshale member) Lower portion contains lenses of green or red shale above massive beds of fine-grained white sandstone. (Lytle sandstone member).

Table 4 (Continued)

Era	Geologic age	Formation & section symbol	Thickness	Portion of watershed	Description
			Feet	Percent	
MESOZOIC	Upper Jurassic	Morrison formation Km	225-245		Red and green shale containing lenticular bodies of dark gray limestone and thin beds of sandstone.
PALEOZOIC	Carboniferous	Lykins formation Cl	180		Gypsum at the top underlain by alternating beds of gray and red sandstone, red and mottled green sandy shale.
		Lyons sandstone Cly	800-850	1.0	Fine-grained, white, pure quartz sandstone 300 feet in thickness underlain by 35 feet of boulder conglomerate, and 500 feet of brick red, cross-bedded sandstone.
		Fountain formation Cf	800-4,500		White to pink arkose and conglomerate, includes near middle an alternating series of red and green shales.
	Ordovician	Manitou limestone Om	50-250	0.7	Consists of thick-bedded gray limestone approximately 200 feet in thickness, underlain by 50 feet of thin-bedded purplish and reddish gray limestone.
	Cambrian	Sewatch Cs	45	0.1	The upper portion is a reddish, calcareous, and glauconitic sandstone below which occurs a cream-colored, pure quartz sandstone, conglomeratic in places near base.
	Pre-Cambrian	Pikes Peak granite Ppg		24.1	Pink granite extensively cut by pegmatite dikes.

1/ The Dawson arkose is classified as Tertiary, Eocene, in the Colorado Springs section, by G. I. Findlay. Later work indicates the Dawson should be classified as Upper Cretaceous and Eocene (?).

110. The upper half of the Laramie formation consists of clay shale interbedded with very fine-grained, iron-stained sandstone. The lower half contains massive beds of fine-grained quartz sandstone separated by sandy shales. Several beds of coal occur in the sandstones.

Cenozoic

111. The Dawson arkose is an extensive deposit of continental sediments, chiefly of fluviatile origin. It consists largely of angular to subrounded fragments of quartz and kaolinized feldspar. The constituents are poorly cemented and form a soft coarse- to medium-grained, cross-bedded, arkosic sandstone with lenses of conglomerate. The lower Dawson contains a persistent andesitic sandstone member beneath which lie interbedded clay, shale, and conglomerate. Although the beds are lenticular, the formation is moderately permeable and generally of low erodibility except in the lower more argillaceous part.

112. The mesa gravels cap tablelands extending eastward from the mountains. The deposits consist mainly of roughly sorted, angular fragments of granite interbedded with sandy layers unconsolidated except for local calcareous cementation.

113. Quaternary alluvium occurs on the bottom lands of the river and its principal tributaries. It consists of lenticular bodies of silt, sand, and gravel. Thickness varies from 10 to 60 feet. It is highly permeable and constitutes an important aquifer.

Structure

114. At one time, the sedimentary rocks almost completely covered the granite of the mountains. Mountain-building forces pressed the

present mountain area upward into its present position. In this earth movement the strata were broken in a number of great fault planes. The movement along the fault planes dragged the older sedimentary rocks into their present steeply dipping attitude. The Pierre shale and all younger rocks that outcrop in the plains area dip 5 to 6 degrees northeastward.

Ground Water

115. Permeable lenses occurring in the Quaternary alluvium, the Dawson arkose, and the Fox Hills sandstone constitute the important aquifers. These aquifers are reliable sources of culinary water. Supplementary irrigation water is obtained from the alluvium along Fountain River.

116. Water in the alluvium generally flows in the direction of flow of the river. Water in the other aquifers generally flows northeastward.

SLOPE

117. Watershed slopes vary from practically 9 percent in the low-lying alluvial flats to as much as 95 percent in some of the mountainous area. Generally speaking, most of the slopes in the eastern two-thirds of the drainage do not exceed 10 percent; in the foothill section topography is somewhat rougher and slopes vary from 10 to 20 percent; and in the mountainous areas slopes are generally in excess of 20 percent and substantial portions run as high as 60 to 90 percent. Table 5 gives the area of the watershed in each of five slope classes.

Table 5. Areal extent of slope classes, Fountain River Watershed.

Slope class	Area	Portion of watershed
Percent	Acres	Percent
0 - 3	121,343	20.4
3 - 6	123,157	20.8
6 - 10	84,566	14.2
10 - 20	56,820	9.6
Over 20	197,653	33.4
Urban	9,696	1.6
Total	593,235	100.0

VEGETATIVE COVER

118. Reports of early explorers and settlers in the Fountain River area state that an abundant and luxurious growth of gramas and bunchgrasses covered the open plains section and that extensive forest cover, broken only by a few meadows, extended over the mountainous portion and the Black Forest area.

119. During the course of settlement and development, cover conditions have changed materially. Today some 12,110 acres are in urban developments, reservoirs, roads, and miscellaneous uses; and 523,349 acres are in range and timberlands and used for grazing, timber production, water supply, recreation, and watershed protection purposes. About 39,053 acres are cultivated and the remaining 18,723 acres are classed as waste or barren.

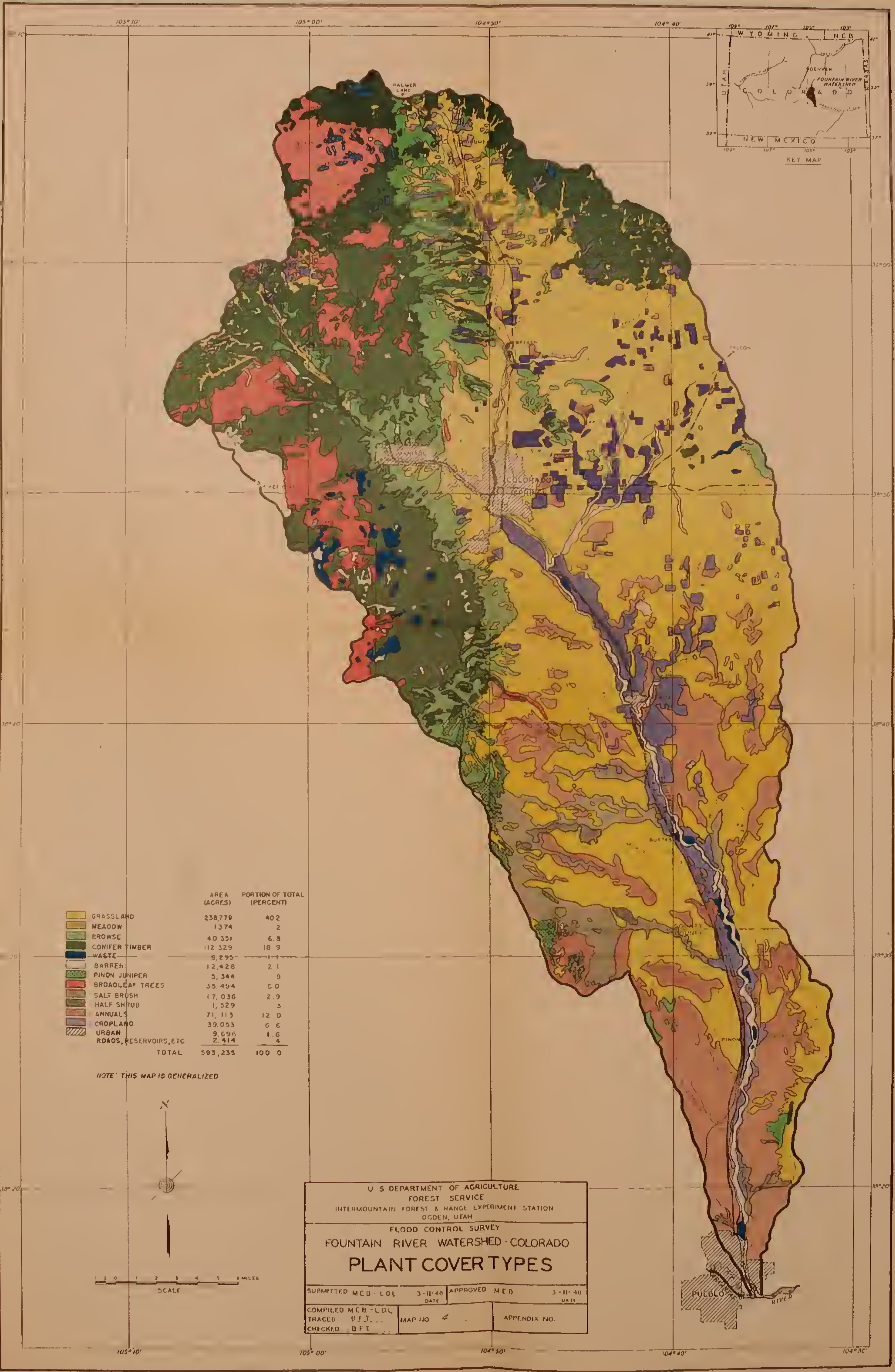
120. The present native vegetation has been classified into 11 type groups. By and large the present vegetative species are the same as those originally native to the watershed but plant density and vigor are greatly reduced and the percentage composition has changed in favor of the less desirable grasses and weeds. In some areas following fire, aspen has replaced coniferous species. A summary of cover type is given in table 6 and the location of types is shown on map 4.

SOILS

121. Soils of the watershed form a complex pattern because of the mountains-plains physiography and the outcropping of 14 separate geological formations. These soils were mapped under 12 broad groups based primarily upon physical characteristics and general origin. The location and extent of each group is shown on map 5, and physical characteristics are summarized in table 7 and discussed below.

a. Group 1 - Sandy upland soils. This group of plains soils, occupying 12.9 percent of the watershed, are derived principally from the Dawson arkose and the Laramie sandstone. They are neutral in reaction, low in plant nutrients, suitable mainly for grazing use, and subject to water and wind erosion when the native grama and bunchgrass vegetation is disturbed or destroyed. Surface runoff from these soils is less than from other plains soils in the watershed. Surface soils are sandy loams, or lighter, and subsoils are permeable loamy sandy to sandy clay loams.

b. Group 2 - Heavy upland soils. About 11.1 percent of the watershed is occupied by this soil group. The soils are



WYOMING
NEB
UTAH
COLORADO
DENVER
FOUNTAIN RIVER WATERSHED
NEW MEXICO
KEY MAP
PALMER LAKE
COLORADO SPRINGS
PUEBLO
RIVER
AREA (ACRES)
PORTION OF TOTAL (PERCENT)
GRASSLAND 238,779 402
MEADOW 1374 2
BROWSE 40 351 6.8
CONIFER TIMBER 112 329 18 9
WASTE 6,295 1 1
BARREN 12,428 2 1
PINON JUNIPER 5,344 9
BROADLEAF TREES 35.494 6 0
SALT BRUSH 17,036 2.9
HALF SHRUB 1,529 3
ANNUALS 71,113 12 0
CROPLAND 39.053 6 6
URBAN 9.696 1.6
ROADS, RESERVOIRS, ETC 2.414 4
TOTAL 593,235 100 0
NOTE: THIS MAP IS GENERALIZED
SCALE
MILES
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FOREST SERVICE
INTERMOUNTAIN FOREST & RANGE EXPERIMENT STATION
OGDEN, UTAH
FLOOD CONTROL SURVEY
FOUNTAIN RIVER WATERSHED · COLORADO
PLANT COVER TYPES
SUBMITTED MEB · LDL 3-11-48 DATE
APPROVED MEB 3-11-48 DATE
COMPILED MEB - LDL
TRACED BFT
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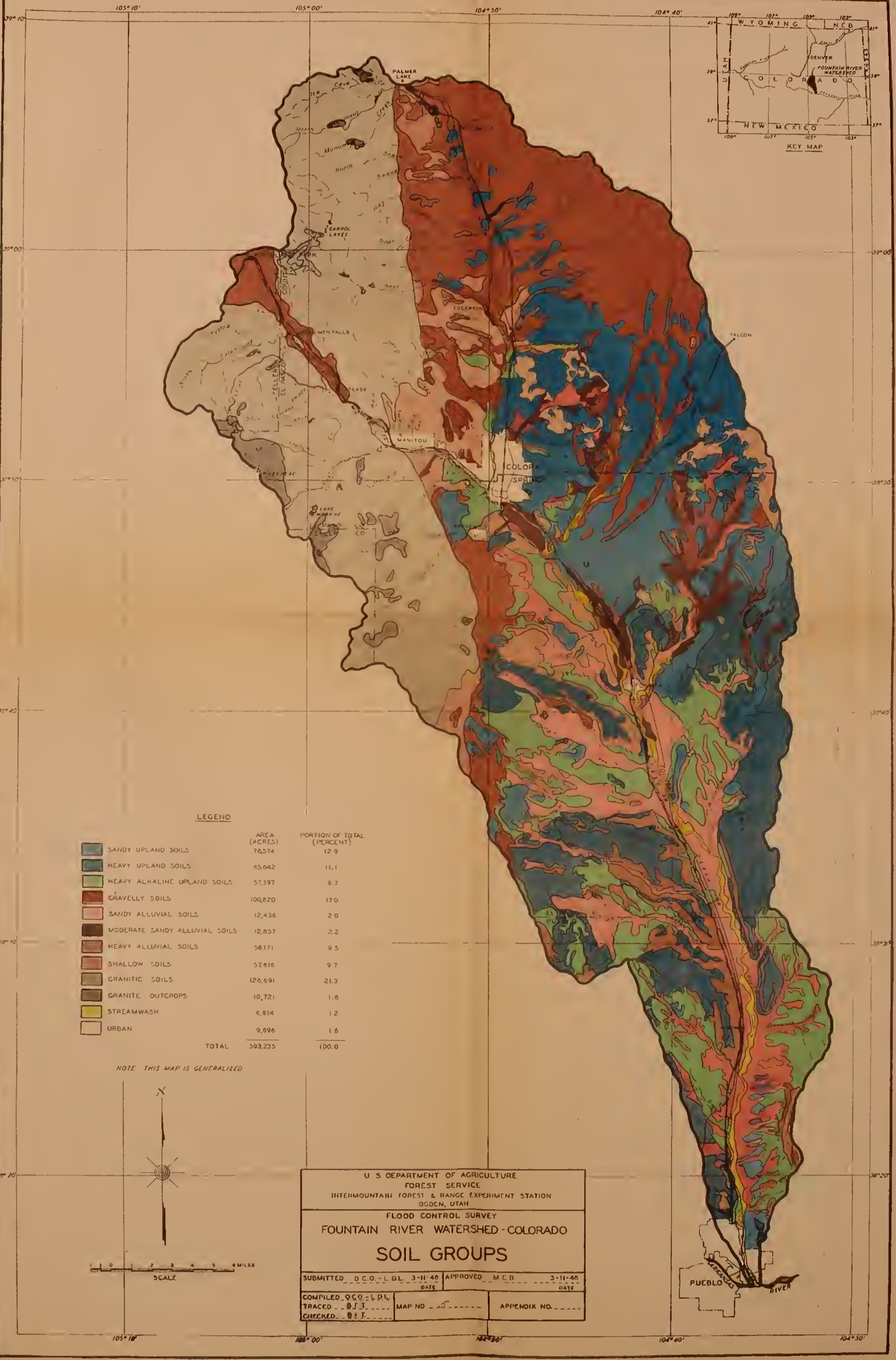
MAP NO 4
APPENDIX NO.
105° 10'
105° 00'
104° 50'
104° 40'
104° 30'



KEY MAP
WYOMING
NEB
UTAH
COLORADO
NEW MEXICO
DENVER
FOUNTAIN RIVER WATERSHED
PALMER LAKE
CARROL LAKES
EDGERTON
FALCON
MTN FALLS
CADE
MANITOU
COLORADO SPRINGS
LAKE MORAINE
PUEBLO
ARKANSAS RIVER
EL PASO
LEGEND
AREA (ACRES)
PORTION OF TOTAL (PERCENT)
SANDY UPLAND SOILS 76,574 12.9
HEAVY UPLAND SOILS 65,642 11.1
HEAVY ALKALINE UPLAND SOILS 57,397 9.7
GRAVELLY SOILS 100,820 17.0
SANDY ALLUVIAL SOILS 12,436 2.0
MODERATE SANDY ALLUVIAL SOILS 12,857 2.2
HEAVY ALLUVIAL SOILS 56,171 9.5
SHALLOW SOILS 57,616 9.7
GRANITIC SOILS 126,691 21.3
GRANITE OUTCROPS 10,721 1.8
STREAMWASH 6,614 1.2
URBAN 9,696 1.6
TOTAL 593,235 100.0
NOTE THIS MAP IS GENERALIZED
N
SCALE
MILES
U S DEPARTMENT OF AGRICULTURE
FOREST SERVICE
INTERMOUNTAIN FOREST & RANGE EXPERIMENT STATION
OGDEN, UTAH
FLOOD CONTROL SURVEY
FOUNTAIN RIVER WATERSHED - COLORADO
SOIL GROUPS
SUBMITTED D.C.O. - L.D.L. 3-11-48 DATE
APPROVED M.E.B. 3-11-48 DATE
COMPILED D.C.O. - L.D.L.
TRACED D.F.T.
CHECKED D.F.T.
MAP NO 5
APPENDIX NO.

Table 6. Extent, general location and composition of general cover types, Fountain River Watershed, 1947.

Type	Area	Portion of total	General location	Important species
	Acres	Percent		
Grassland	238,779	40.2	Dry plains on sandy or alluvial soils	Blue grama, red three-awn, ring muhly, sand dropseed
Meadow	1,374	.2	Low swales and bottomlands with high water table	Sedges, rushes, timothy, saltgrass
Browse	40,351	6.8	Transition zone lower mountain slopes	Oakbrush, mountainmahogany, skunk-bush
Conifer timber	112,329	18.9	Mountainous areas and Black Forest	Ponderosa pine, Douglas-fir, limber pine, spruce
Waste	6,295	1.1	Rocky ridges, inaccessible areas	
Barren	12,428	2.1	Rocky areas, gravel slides, etc.	Little or no vegetation present
Pinon-juniper	5,344	.9	Foothill zones	Pinon pine, juniper, oakbrush
Broadleaf trees	35,494	6.0	Old burns and well-watered draws	Aspen, cottonwood, snowberry
Saltbush	17,036	2.9	Overflow bottoms with high saline concentration	Saltbush, rabbitbrush, saltgrass, sacaton
Half shrub	1,529	.3	Overgrazed areas	Gutierrezia, silver sage, galleta
Annuals	71,113	12.0	Overgrazed grass lands and abandoned fields	Russianthistle, lambsquarter, atriplex, grama
Subtotal	542,072	91.4		
Cropland	39,053	6.6	Bottomlands and flat plains area	
Urban	9,696	1.6	Pueblo, Colorado Springs, Manitou, Fountain	
Reservoirs	1,421	.2	Largely in mountainous section	
Roads and misc.	993	.2		
Grand total	593,235	100.0		

Table 7. Some physical characteristics of soil groups, Fountain River Watershed

Soil group No.	Soil group	Acres	Percent of total watershed	Parent material	Dominant native vegetation	Texture		Infiltration rate*			Erosion
						Surface	Subsoil	Depth	Present	With program	
1	Sandy upland soils	76,574	12.9	Dawson arkose Laramie sand-stone	Grama Bunchgrass	Loamy sand to sandy loam	Loamy sand to sandy clay loam	20-30 inches	1.19	1.60	Slight
2	Heavy upland soils	65,642	11.1	Pierre shale Niobrara limestone	Grama Wheatgrass	Loams to clay loams	Clay	14-20 inches	0.74	0.83	Moderate to severe
3	Heavy alkaline upland soils	57,397	9.7	Pierre shale	Galleta Grama	Clay	Clay	4-24 inches	0.45	0.50	Very severe
4	Gravelly upland soils	100,820	17.0	Dawson arkose Mesa gravels	Grama Ponderosa pine Chaparral	Gravelly sandy loam	Gravelly sandy loam	4-24 inches	0.82	0.92	Moderate
5	Sandy alluvial soils	12,436	2.0	Sandy alluvium	Grama	Loamy sand	Sandy loam	36± inches	1.08	1.30	Slight
6	Mod. sandy alluvial soils	12,857	2.2	Mixed alluvium	Grama	Fine sandy loam	Clay loam	36± inches	1.03	1.60	Slight
7	Heavy alluvial soils	56,171	9.5	Heavy alluvium	Saltgrass Salt bush	Clay	Clay	36± inches	0.59	0.81	Severe
8	Shallow soils	57,616	9.7	Dawson arkose Pierre shale Laramie sand-stone	Chaparral Grama	Sandy loam to clay	Bedrock or sandy loam to clay	4-12 inches	0.45	0.50	Slight to severe
9	Granite mountain soils	126,691	21.3	Pikes Peak granite	Ponderosa pine, fir, spruce, aspen	Gravelly loamy sand to sandy	Gravelly loamy sand	4-30 inches	2.11	2.38	Moderate
10	Rock outcrops	10,721	1.8	Pikes Peak granite	Barren, Pine Grama	Bedrock or gravelly loamy sand	Bedrock	0-4 inches	-	-	Geologic
11	Stream wash sands and gravels	6,614	1.2	Mixed alluvium	Barren	Gravels & sands	Gravels & sands	72± inches	-	-	Undifferentiated
12	Urban	9,696	1.6	Variable	-	-	-	-	-	-	Undifferentiated

* fc values

derived from shales, limestones, and outwash material. A small percentage of the soils are being cultivated under irrigation but most are being used for grazing purposes. Erodibility varies from slight to moderate but some of the heavier soils have a tendency to gully excessively. Moderate surface runoff is produced. Surface soils are usually clay loams and subsoils are clay.

c. Group 3 - Heavy alkaline upland soils. This group of soils is formed from Pierre shale, a thinly laminated formation containing sufficient alkaline salts to give a high dispersion to the soils. These soils are highly colloidal, have high water-holding capacities, possess very low infiltration rates, are highly susceptible to erosion, and have both clay surface soils and subsoils. They occupy 9.7 percent of the watershed and are some of the heaviest sediment contributors.

d. Group 4 - Gravelly upland soils. Seventeen percent of the watershed is occupied by gravelly upland soils which are derived from the Dawson arkose and Mesa gravels. Erodibility of these soils varies from slight to moderate, infiltration rates are moderate, water-holding capacity is low, and runoff from the shallow members of the group is rather high. The profiles are gravelly sandy loams throughout.

e. Group 5 - Sandy alluvial soils. This group occupies only 2.0 percent of the watershed. It has moderately high infiltration rates, relatively low runoff, and slight to moderate erosion rates. Profiles are variable but in general loamy sand surfaces are found over sandy loam subsoils.

f. Group 6 - Moderately sandy alluvial soils. This small group of soils occupies 2.2 percent of the drainage but includes some of the best cropland soils. Moderate infiltration rates and moderate erodibility are characteristics of the soils. Profiles consist of friable fine sandy loams overlying clay loam subsoils.

g. Group 7 - Heavy alluvial soils. This 9.5 percent of the watershed is a heavy contributor of sediment. The soils can be cultivated under irrigation if concentration of soluble salts is not too high. Infiltration rates are low and erodibility is severe. Profiles are generally clay throughout and often contain soluble salts in injurious quantities.

h. Group 8 - Shallow soils. Shallow soils are derived from shales, arkosic materials, limestones, and sandstones. They occupy 9.7 percent of the steeper and rougher portions of the watershed. Infiltration rates are low, erosion is moderate and profiles of these soils are quite shallow and immature.

i. Group 9 - Granite mountain soils. This group is the largest in the watershed occupying 21.3 percent of the drainage. They are derived entirely from the Pikes Peak granite and are confined to the mountainous section. These soils have relatively high infiltration rates but because many of them are shallow, runoff will occur during times of abundant moisture, especially where the bedrock is not fractured. Because of the coarse nature of the disintegrated granite and lack of finer materials, the soils are easily eroded when the cover is disturbed and

soil movement is clearly evident. Profiles consist of relatively thin surface layer of coarse sandy loams overlying granite bedrock which may be found in all stages of weathering and decomposition.

j. Group 10 - Rock outcrops. One and eight-tenths percent of the watershed consists of granite rock outcrops with sparse vegetation and little or no soil development. Because of the fractured condition of this rock, the large amount of talus material present, and its limited occurrence in the watershed, this group has contributed little to the accelerated flood and sediment problems.

k. Group 11 - Stream wash sands and gravels. This material is confined to the stream channels themselves and occupies 1.2 percent of the watershed.

l. Group 12 - This classification includes all the urban areas and represents 1.6 percent of the total drainage.

EROSION

General

122. Erosion conditions vary widely within the watershed as shown by map 6 and table 8. Three general provinces may be distinguished in which the degree of erosion and distribution of erosion classes are similar. These erosion provinces are as follows: (a) the mountains; (b) the northern plains; and (c) the southern plains.

Mountain Province

123. The mountain province, covering 144,598 acres, has been subjected mainly to moderate sheet erosion accompanied by occasional gullies.

Eighty-seven and five-tenths percent, or 126,582 acres of the total area of the province falls in this class. Severe sheet erosion accompanied by occasional gullies covers an area that has burned in the past and has since largely grown back to aspen. Areas that have been damaged but slightly from accelerated erosion represent only 3.1 percent of the province. These small areas occur on those watersheds that have been protected from fires and grazing for many years.

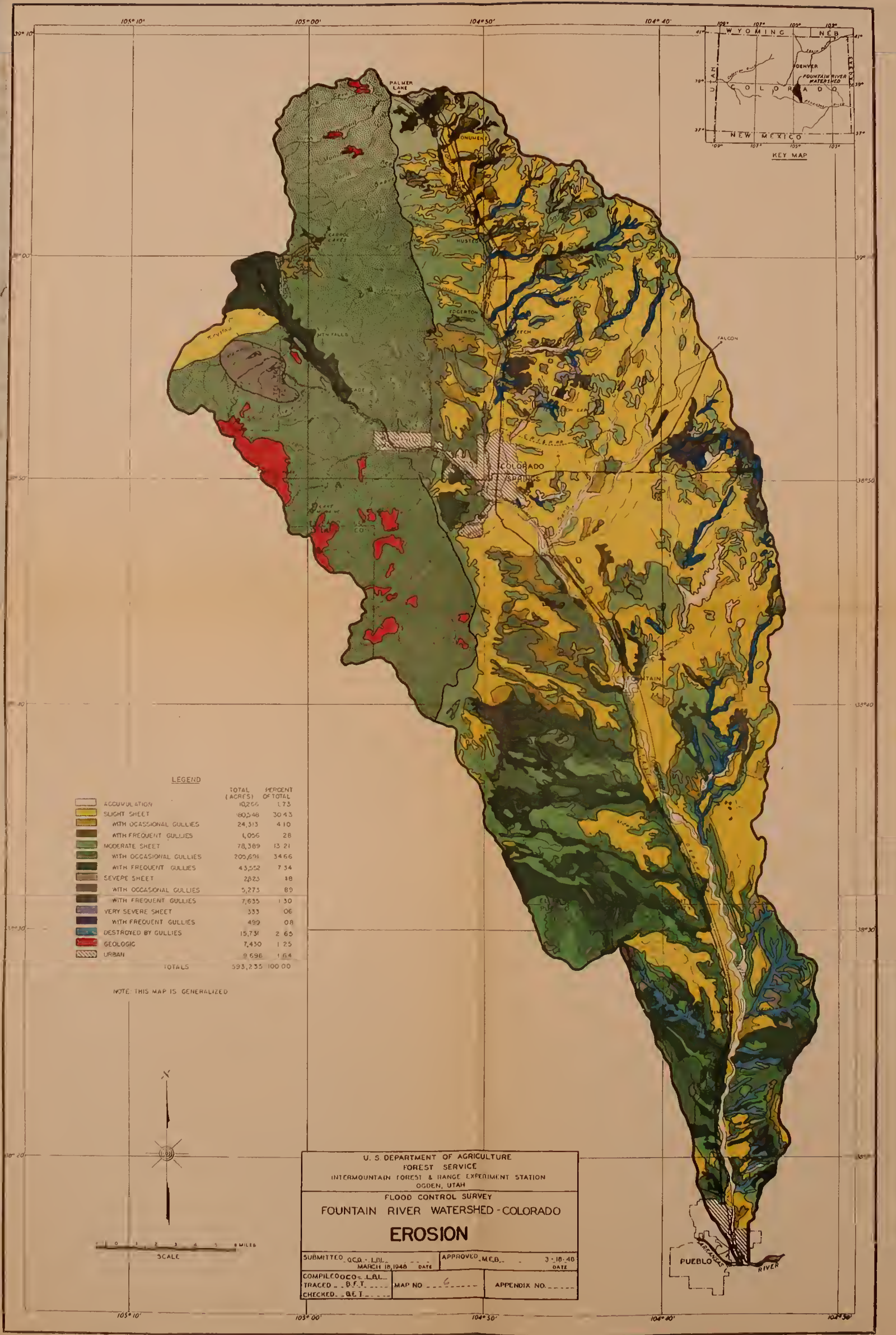
124. Although the infiltration rates are relatively high, the nature of the granitic soils is such that they are unstable physically and consequently are easily eroded when misused. The high percentage of moderate sheet erosion bears this out.

125. Geologic, or normal, erosion occurs on small areas of granitic outcrop which are generally barren but may have a small amount of herbaceous or open-forested cover upon them. Little or no soil has been formed on these areas but because of the porous condition of the highly fractured bedrock, runoff and sediment from these areas are generally slight. However, only 5.1 percent of the mountain province is found in this class.

Northern Plains Province

126. In the northern plains province, comprising 210,859 acres, erosion conditions are most serious in and adjacent to the stream channels. Most of the channels have increased their width several fold in the last 35 years and it is probable that no well-defined channels were present in some of the valleys before the region was settled.

127. Approximately one-fourth of the total province area is classed as having gullies varying in intensity of occurrence from occasional to



105° 10'
105° 00'
104° 50'
104° 40'
KEY MAP
WYOMING
NEB
UTAH
COLORADO
NEW MEXICO
DENVER
FOUNTAIN RIVER WATERSHED
PALMER LAKE
MONUMENT
HUSTED
EDGERTON
FALCON
COLORADO SPRINGS
FOUNTAIN
PUEBLO
ARKANSAS RIVER
LEGEND
TOTAL (ACRES) PERCENT OF TOTAL
ACCUMULATION 10,266 1.73
SLIGHT SHEET 180,548 30.43
WITH OCASSIONAL GULLIES 24,313 4.10
WITH FREQUENT GULLIES 1,056 .28
MODERATE SHEET 78,389 13.21
WITH OCCASIONAL GULLIES 205,691 34.66
WITH FREQUENT GULLIES 43,552 7.34
SEVERE SHEET 2,823 .48
WITH OCCASIONAL GULLIES 5,273 .89
WITH FREQUENT GULLIES 7,635 1.30
VERY SEVERE SHEET 333 .06
WITH FREQUENT GULLIES 499 .08
DESTROYED BY GULLIES 15,731 2.65
GEOLOGIC 7,430 1.25
URBAN 9,698 1.64
TOTALS 593,235 100.00
NOTE: THIS MAP IS GENERALIZED
SCALE
MILES
U. S. DEPARTMENT OF AGRICULTURE
FOREST SERVICE
INTERMOUNTAIN FOREST & RANGE EXPERIMENT STATION
OGDEN, UTAH
FLOOD CONTROL SURVEY
FOUNTAIN RIVER WATERSHED - COLORADO
EROSION
SUBMITTED OCO.-LBL. MARCH 18, 1948 DATE
APPROVED M.E.B. 3-18-48 DATE
COMPILED OCO.-LBL.
TRACED B.F.T.
CHECKED B.F.T.
MAP NO 6
APPENDIX NO.
105° 10'
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104° 30'
104° 20'

Table 8. Erosion conditions, Fountain River Watershed.

Erosion class	Mountains			Northern plains			Southern plains			Total acres
	Acres	% of total erosion class	% of province area	Acres	% of total erosion class	% of province area	Acres	% of total erosion class	% of province area	
Accumulation	-			3,048	29.7	1.4	7,218	70.3	3.0	10,266
Slight sheet	4,396	2.5	3.1	104,944	58.1	49.8	71,208	39.4	29.9	180,548
with occasional gullies	1,120	4.6	0.8	11,900	48.9	5.6	11,293	46.5	4.7	24,313
with frequent gullies	-			902	85.4	0.4	154	14.6	0.1	1,056
Moderate sheet	-			40,879	52.1	19.4	37,510	47.9	15.8	78,389
with occasional gullies	126,582	61.5	87.5	26,906	13.1	12.8	52,203	25.4	21.9	205,691
with frequent gullies	-			4,151	9.5	2.0	39,401	90.5	16.6	43,552
Severe sheet	-			1,093	38.7	0.5	1,730	61.3	0.7	2,823
with occasional gullies	4,640	88.0	3.2	254	4.8	0.1	379	7.2	0.2	5,273
with frequent gullies	-			3,686	48.3	1.7	3,949	51.7	1.7	7,635
Very severe sheet	-			333	100.0	0.2	-			333
with frequent gullies	-			499	100.0	0.3	-			499
Destroyed by gullies	-			5,283	33.6	2.5	10,448	66.4	4.4	15,731
Geologic	7,430	100.0	5.1	-			-			7,430
Urban	430	4.4	0.3	6,981	72.0	3.3	2,285	23.6	1.0	9,696
Total	144,598	24.4	100.0	210,859	35.5	100.0	237,778	40.1	100.0	593,235

frequent, with a portion of this area, 5,283 acres, being so severely gullied that the land is considered destroyed for crop production. Short gullies adjacent to the channels and in other areas have lowered the agricultural value of the surrounding land.

128. Within the Black Forest area, moderate sheet erosion is the most prevalent form of accelerated erosion due to the shallow soil depths, excessive slopes, and inadequate litter accumulation. Outside the Black Forest the area in general has suffered only slight sheet erosion but small areas of severe and very severe sheet erosion, totaling 5,865 acres, present a serious problem. Wind erosion has occurred on some of the sandy soils and is found to some extent on 40 percent of the province.

Southern Plains Province

129. The southern plains province, comprising 237,778 acres, is the most seriously eroded province of the three. Nearly one-third of the area has been subjected to a combination of both sheet and gully erosion, which amounts to 117,827 acres. Of this amount, 10,448 acres of land is classed as having been destroyed for crop production.

130. Deep vertical side gullies, progressing headward and widening by bank caving, have greatly reduced the agricultural value of large areas of irrigated and range land. The network of drainage lines resulting from gullying and accelerated sheet erosion with its accompaning rill development has materially increased both the rate and volume of surface runoff. Erosion losses are increasing year after year as the vegetal cover on the range and watershed lands is depleted and runoff increases.

131. Soil loss by sheet erosion is serious over most of the province and has decreased the infiltration and productivity rates. In addition to 117,827 acres of land that has been subjected to both sheet and gully erosion, another 39,240 acres has been damaged by moderate and severe sheet erosion. Only 71,208 acres, or approximately 30 percent of the province, has sustained only slight sheet erosion losses. Accelerated erosion upstream has resulted in the covering of 7,218 acres, or 3 percent of the area, with depositional material and generally has lowered production of the land so affected.

132. Some degree of wind erosion has occurred on slightly less than 15 percent of the province. The main reason for this limited extent is that most of the soils are moderate and heavy textured and are not as susceptible to wind erosion when mismanaged as are the more sandy soils found in the northern province.

Sedimentation

133. Sediment deposited in reservoirs within the Fountain River watershed amounts to 70 acre feet annually. Additional amounts are also deposited in irrigation canals and ditches.

134. Sediment originating on the watershed but deposited elsewhere amounts to 477 acre feet annually as determined by Corps of Engineers sedimentation sampling of the Fountain River at Pueblo. Of this 477 acre feet, 75 acre feet are deposited in the John Martin Reservoir, 32 acre feet pass through the reservoir, 100 acre feet are deposited in irrigation systems between Pueblo and Martin Reservoir and the remaining 270 acre feet in the Arkansas River and flood plain.

135. It is estimated that 272 acre feet of the 477 acre feet are cut from the banks of the Fountain River and its principal tributaries and the remaining 205 are the result of surface erosion on the uplands.

136. In order to determine rates of sediment production from various watershed areas, detailed sedimentation surveys were made of four reservoirs. Although these reservoirs are not in Fountain River drainage, they are located in areas with similar sediment producing characteristics. The drainage area above the first three reservoirs is characterized by soils from soft shale material easily eroded whereas above Castlewood sandy material predominates.

137. The following, table 9, indicates the estimated present sedimentation characteristics of the watershed as determined from the reservoir studies and other data.

Table 9. Sedimentation characteristics, Fountain River Watershed.

Drainage and source of sediment 1/	Watershed area	Annual sedimentation	
		Rate per sq. mi.	Total
	Sq. mi.	A. ft.	A. ft.
Kettle and Pine Creeks	27		
Land erosion		0.10	3
Bank cutting		-	8
Youngs Hollow	38		
Land erosion and bank cutting		0.40	15
Fountain River	927		
Land erosion		0.22	205
Bank cutting		-	272

1/ Measured at mouth of the stream.

LAND AND WATER ECONOMY

HISTORY OF DEVELOPMENT

138. The development of the watershed began with the influx of gold seekers following the discovery of gold in the Pikes Peak region in 1858. Early settlers found a small stream (then known as "Fountaine Qui Bouille" - Boiling Spring Creek) lined with a heavy growth of cottonwood and willow, luxuriant grasses in the valley, and ample grass cover on the plains and on the mountain sides (2).

139. Small herds of cattle were grazed in the lower part of the watershed prior to 1861 and the first known band of sheep came to the valley in 1862. The first great impetus to the livestock industry occurred during the Civil War and continued until all available range land was heavily stocked. The second boom occurred from 1880 to 1885 followed by a third between 1917 and 1921 when World War I increased the demand for beef. These developments resulted in the grazing of many more cattle than the forage on the range could support, especially during years of below-normal rainfall. Severe depletion occurred on many areas.

140. In 1860 a small tract of irrigated land indicated the agricultural value of the Fountain Valley and by 1861 much of the arable land was under cultivation. Mining communities served as ready markets for agricultural products and the establishment of a flour mill in 1862 added incentive to the production of grain.

141. Industrial development began with the discovery of gold. Rail transportation was provided in 1871 when the Denver and Rio Grande Western Railroad constructed a line to Colorado Springs. The city of Pueblo was incorporated in 1885. In 1886, Colorado Springs was incorporated and in 1920 annexed Colorado City to the west.

142. The Pikes Peak Timber Reserve was created in 1892. Numerous additions, eliminations, and consolidations since that time have resulted in the present Pike National Forest of which 110,874 acres lie within the watershed. During the period 1850 to 1853 much of the timberlands in the vicinity of Pikes Peak were burned over, and about 1870 more than 10,000 acres in the northwestern part of the watershed were burned. As early as 1903 steps were taken toward reforestation of the burned areas.

POPULATION

143. The total population of the watershed on the basis of the 1940 census is estimated at 64,521 as shown in table 10. The estimated population of Colorado Springs in 1940 was 36,789, and that portion of Pueblo in the watershed about 19,000. Rural nonfarm population is about 11 percent of the total population and includes small towns and suburban subdivisions. Rural farm population is estimated at 1,396 or about 2 percent of the watershed total.

144. The total population per square mile is 69.6 persons and the rural farm population 1.5 persons per square mile. The rural population is largely in the northeastern section, the southern portion is sparsely settled, and the mountainous western part supports very few rural farm families.

145. The growth in population has been erratic. Colorado Springs increased at a fairly rapid rate up to 1910 but has increased slowly since then. The rate of population increase of Pueblo has fluctuated widely. The farm population has followed the typical dryland pattern of rapid increases following good years and population losses after

poor years. Except for an increase in persons on part time farms, the recent trend in farm population has been downward.

146. The summer population of Colorado Springs, Manitou Springs, and surrounding areas is at least double the yearlong population with a continuing upward trend. The relatively cool summer climate, natural scenic splendor and other features have made this area a favorite and extensively used recreational spot especially for the residents of the more arid areas immediately to the east. Each year there is an increased influx of dude ranch guests, sightseers, and other vacationists to enjoy the recreational opportunities afforded.

LAND OWNERSHIP AND TENURE

Classes of Land Ownership

147. There are several distinct classes of land ownership in the Fountain River Watershed. Almost two-thirds of all the land is owned by private interests. Less than one-fifth of the individually owned land is held by nonresident owners.

148. Federal agencies control about 29 percent of the land area. The national forest land is confined to the rough broken mountainous areas in the western portion. Camp Carson, a permanent military post of 57,730 acres, south of Colorado Springs and Peterson Field, about 2,880 acres, east of the same city occupy about 10 percent of the watershed.

149. Land owned by the State of Colorado is scattered throughout the plains portion of the watershed with some concentration on the watershed divide east of Fountain. Camp Carson includes some 22,000 acres which formerly was in state ownership. The city of Colorado Springs owns

Table 10. Population data, Fountain River Watershed, Colorado.

	1890	1900	1910	1920	1930	1940
El Paso County						
Urban				30,105	33,237	36,742
Rural farm					6,091	5,339
Rural nonfarm					10,242	11,944
Total	21,259	31,602	43,321	44,027	49,570	54,025
Pueblo County						
Urban				43,050	50,096	52,109
Rural farm					7,071	6,301
Rural nonfarm					8,871	10,460
Total	31,491	34,448	52,223	57,638	66,038	68,870
Fountain River Watershed						
Urban						55,709
Rural farm						1,396
Rural nonfarm						7,416
Total						64,521
Colorado Springs						36,789
Pueblo						52,162

about 11,000 acres, largely in the mountainous area which is used exclusively for municipal water supply purposes.

150. Table 11 presents the various ownership classes in more detail.

Land Tenure

Nonfarm land

151. The Pikes Peak Timber Reserve, now known as the Pike National Forest, was created in 1892 and has been under Forest Service administration since its origin. The Camp Carson area was acquired by the War Department in 1941-42. Prior to this time, most of the land in the camp area was used for grazing and was owned and operated by private owners or leased from the state. In 1942, Peterson Field was developed from the municipal airport by the acquisition of additional acreage most of which had been farm land.

152. In 1908, Colorado Springs made the first purchase of land on the north side of Pikes Peak for water supply purposes. Subsequent purchases and grants have enlarged this municipal watershed to its present size.

Farm land

153. In the Fountain River drainage, there are about 355,300 acres of farm land and about 400 farm operators. A summary of the tenure groups together with the acreage owned and rented by each is set forth in table 12. It is important to note that 70 percent of the operators are owners or part-owners and control about 84 percent of the total farm land including the 87,700 acres which are rented by part-owners. This pattern should favor the successful installation

of an upstream flood control program on farm land. The remaining 16 percent of the farm land is operated by tenants. Rental contracts are of two types: Share-crop and cash. The usual length of lease is 1 year with renewal privileges. Generally speaking, the tenant type of operation is the least desirable because of the exploitative farming which is usually practiced.

154. More than one-third of the operators have been on the farms for 10 years or more. In recent years there has been a tendency toward more stability in this respect. Likewise, the present trend is toward outright ownership rather than the part-owner and tenant type of operation.

LAND USE AND MANAGEMENT

General

155. About 67 percent of the watershed lands is used for grazing purposes with some incidental timber production. Fourteen percent has been set aside as municipal or private watersheds or for recreational purposes. Less than 7 percent of the watershed lands is in cultivation and the remaining 12 percent is used for military establishments or urban developments. Table 13 shows the classes of land use and areal extent of each class.

Cultivated Lands

156. Of the 39,053 acres in cultivation, about 44 percent is planted to corn; 17 percent to other row crops such as sorghum, beans, sugar beets, and vegetables; 8 percent to small grains; 27 percent to hay, alfalfa, and tame pasture; and the remaining area is fallow or idle.

Table 11. Status of land ownership, Fountain River Watershed, 1947.

Type of ownership	Area	Portion of watershed
	Acres	Percent
Private		
Individual	287,588	48.5
Corporation	86,036	14.5
Total private	373,624	63.0
Federal		
National forest	110,874	18.7
Military establishments	60,610	10.2
Total Federal	171,484	28.9
Other public		
State	26,643	4.5
County	788	.1
Municipal	11,000	1.9
Total other public	38,431	6.5
Urban	9,696	1.6
Grand total	593,235	100.0

Table 12. Type of farm operator and land in farms controlled by each, Fountain River Watershed, 1947.

Tenure group	Operators		Land in farms			
	Number	Percent	Owned	Area rented	Total	Percent
			Acres	Acres	Acres	
Owner	202	51	97,668		97,668	27.5
Part-owner	76	19	114,479	87,739	202,218	56.9
Renter	118	30	-	55,413	55,413	15.6
Total	396	100	212,147	143,152	355,299	100.0
Percent			59.7	40.3	100.0	

Table 13. Land use, Fountain River Watershed, 1947.

Type of use	Area	Portion of watershed
	Acres	Percent
Cropland		
Irrigated	15,000	2.5
Dry-farm	24,053	4.1
Total cropland	39,053	6.6
Water supply areas 1/		
National Forest	72,339	12.2
Municipal and private	11,000	1.9
Total	83,339	14.1
Miscellaneous range and woodland range	400,537	67.5
Military establishments	60,610	10.2
Urban	9,696	1.6
Watershed total	593,235	100.0

1/ These lands have been set aside for use as municipal water source areas and all other types of use have been excluded.

Irrigated lands

157. A high percentage of the irrigated acreage is located along Fountain River between Colorado Springs and Pueblo. A few small fields are found along Monument Creek and in local projects on a few of the tributary streams. Water is supplied largely by direct diversion from Fountain River and off-stream reservoirs. Principal irrigated crops are corn, alfalfa, small grain, and other feed crops.

158. Considerable portions of the irrigated area, the most valuable land in the watershed, are subject to damage and destruction from bank cutting and lateral widening of the Fountain River channel. In some instances, sediment in diverted water as well as that carried by side drainages constitute a major problem.

159. Because of inadequate water to irrigate all the land under ditches, proper irrigation methods, crop rotations, and other proved cropping methods are not applied on many farms. The application of manure is generally practiced but is not sufficient to maintain the fertility of the soil. Since irrigation is carried on largely by direct diversion, the characteristics of the channel and stream flow are of major importance to the irrigation enterprises. Further discussion of water supply problems and flood damage relationships may be found elsewhere in the report.

Dry-farm lands

160. The dry-farm land is located adjacent to the irrigated fields and in scattered tracts in the central and northern portions of the plains area where precipitation is most favorable for dry-farming. About 50 percent of the 24,000 dry-farm acres is in corn,

30 percent is in tame hay and sorghum feed, and the remaining acreage in the production of beans, small grains, and other crops, or lying fallow and idle.

161. Cropping methods vary from the most progressive type of conservation farming to the most destructive type of soil exploitation. Cultivation up and down the slope can be found across the fence from a well-terraced field. Normally strip cropping has not been adopted as a cultural method. Subsoils have been bared on many fields and considerable loss of topsoil is taking place. Gullies are dividing the fields making them difficult as well as costly to cultivate. Because of steep slopes, shallow soils, and erosion conditions, considerable areas are not suitable for cultivation and should be retired to grass. This desired adjustment in land use is in direct conflict with the present general trend wherein some grassland is being plowed and sown to wheat. With the establishment of a demonstration project and organization of soil conservation districts and the activities of the Agricultural Extension Service and the ACP program there now exists some acreage on which conservation measures are in effect. However, continued accelerated erosion and declines in yield and fertility are taking place on many of the dry-farm lands.

Water Supply Areas

162. One part of about 72,300 acres of Pike National Forest land which has been set aside as a municipal water source area was closed to grazing prior to 1900; most of the remaining portion was closed about 1916. This acreage has been a part of the national forest since 1892 and has been under management since that date. Many thousands of acres

which had been burned prior to 1900 have been reforested with Douglas-fir, ponderosa pine, and other species. Some of these plantations are now about 40 years old and are providing improved protection to the sites. No timber cutting has been permitted for many years. A few small areas have been set aside for recreational purposes.

163. Most of the non-Federal land set aside for water supply purposes forms an integral part of the Colorado Springs water supply system. Several storage reservoirs and pipe lines have been constructed on these lands. Resident caretakers together with boundary fences are most effective in preventing grazing trespass and other use. Some of the best watershed cover conditions are found on these lands.

164. The Pike National Forest management plan calls for adjustments of grazing use on 38,535 acres of existing national forest lands as conditions permit. This action is considered necessary to provide additional satisfactory water sources and for the protection of other watershed values.

Military Establishments

165. Camp Carson, which recently became a permanent military post, and Peterson Field have been closed to all types of nonmilitary use since acquisition by the War Department in 1941-42. Prior to the war the areas were parts of farm and ranch enterprises, substantial portions of which were owned by the State of Colorado and corporations. At that time, the estimated grazing capacity of the 6,610 acres amounted to about 10,530 a.u.m.

166. Some of the land has become sites for barracks, hangars, offices, and other buildings but the major portion has been used extensively for rifle ranges and miscellaneous maneuvers. The exclusion of livestock and other use restrictions have permitted the vegetative cover to make extensive gains over much of the area. The occurrence and density of desirable species has greatly increased. Old fields have become stabilized with weeds and grass species. Old gullies show definite signs of stabilization. Many formerly bare areas are showing definite recuperation.

167. Prior to closure, the grazing capacity was estimated to be about 9,570 a.u.m. for Camp Carson and 960 a.u.m. for Peterson Field, or a total of 10,530 a.u.m. Although former operators were forced to liquidate their livestock holdings or find other grazing areas, there is no evidence at the present time of any permanent ill effects from such closure. Since it cannot be definitely determined if or when any of this acreage will revert to private ownership, nor whether grazing will be permitted in the future, for purposes of this report, forage produced on this 60,610 acres was not considered.

Miscellaneous Range and Woodland-Range

168. The remaining watershed acreage, excluding urban areas, comprises 400,537 acres of miscellaneous range and woodland-range, 362,002 acres of which is in non-Federal ownership. About 56 percent is in grass, 17 percent in annual grasses and weeds, 11 percent in conifer timber, 9 percent in browse, and 7 percent in miscellaneous cover including pinyon-juniper, aspen, and cottonwood, saltbush, half shrubs, waste, and other minor vegetative types.

169. The early growth of the livestock industry resulted in the grazing of more stock than the forage growth could support so that severe depletion occurred on many areas. Under the homestead laws, many large units were broken up and the number of small operators greatly increased. Since each new operator acquired varying numbers of stock, in the aggregate, the range remained as greatly overstocked as it has been under the large ranch organizations.

170. Many range operators, especially on small ranches, have not adopted the most progressive methods of range management. Yearlong grazing without rotation or adjustment of grazing use to actual carrying capacity is the general practice. However, lands may be grazed as little as 8 months during the year if winter conditions are severe. Some operators move stock from pastures to mowed hay fields where some additional feed is provided during the winter season. Stock water facilities are fairly well developed. The practice of salting near water development is prevalent. Where operators have practiced some form of good management, the condition of their ranges clearly reflects improved range husbandry. Observations in Camp Carson and at other points prove that most ranges potentially have rapid recuperative ability if proper management and treatment are applied.

171. Based on the most reliable recent statistics, it is estimated that 1,116 horses and mules, 7,892 beef cattle, 2,847 dairy cattle, 3,862 yearling calves, and 3,778 sheep and goats grazed the watershed lands in 1947. During the past 2 years, livestock numbers have fallen below long-time average figures as a result of several factors, the more important of which are: (a) favorable markets for

mature stock and high replacement costs resulting in the sale of many cattle without replacement; (b) embargo on Mexican cattle eliminating one source of replacement stock.

172. To secure an indication of the average stocking on these range lands, it was assumed that horses, mules, beef cattle, sheep, and goats graze the range for at least 9 months during the year, that calves graze 6 months, and dairy cattle for 3 months. Thus the total range forage required for the season is 10,316 animal unit months based on the estimated 1947 stocking figures. This requirement is summarized in table 14.

173. When compared to the range forage requirements, the actual grazing capacity is inadequate to meet the demand. A summary of carrying capacity estimates is given in table 15. This table includes not only the forage produced on the native ranges but also that which is available from hay stubble during the grazing season.

174. By comparing the above figures, it is obvious that the range lands are overutilized. Range forage requirements, based on estimated 1947 stocking rates, are 114 percent of the range forage produced. In other words, the estimated grazing capacity is only seven-eighths of the grazing use. These comparisons are made on the basis of a 9-month range season. The situation is more critical than indicated when it is realized: (1) that the period of use frequently exceeds 9 months and in some instances is yearlong; (2) that the comparison is based on 1947 livestock numbers which admittedly are below average; and (3) that recent favorable weather conditions have encouraged vegetative growth beyond that which can normally be expected to continue.

Table 14. Range forage requirements, Fountain River Watershed, 1947

Class of livestock	Number of head	Months range use	Total annual use	Head per a.u.
	Number	Number	a.u.m.	
Horses and mules	1,116	9	10,044	1
Beef cattle	7,892	9	71,028	1
Dairy cattle	2,847	3	8,541	1
Yearling calves	3,862	6	13,903	1-2/3
Sheep and goats	3,778	9	6,800	5
Total	19,495		110,316	

Table 15. Grazing capacity estimates, Fountain River Watershed, 1947

Source of forage	Area	Grazing capacity	Acres per a.u.m.
	Acres	a.u.m.	Number
Grassland	201,117	57,462	3.5
Meadow	610	469	1.3
Browse	31,477	6,295	5.0
Conifer	38,839	3,884	10.0
All others	74,442	7,444	10.0
Hay stubble	10,500	21,000	.5
Waste, barren, misc.	15,517	-	-
Total		96,554	

Timberland

General

175. There are 153,800 acres of timberland, exclusive of brushland, within the watershed. Because much of the private timberland has been or is being grazed, some of this acreage is also included in the figures mentioned in the discussion of range lands. The segregation of the timberland acreage into Federal and non-Federal lands by timber types is shown in table 16. Table 17 presents the estimated timber volumes of the more important species by five broad classes of ownership.

176. Prior to acquisition by the War Department in 1941-42, the small acreage of timberland in the military areas was managed in the same manner as other patented lands. For the most part, it was grazed by livestock and cut over whenever a merchantable volume became available. Since acquisition, these lands have been managed for entirely different purposes. Livestock have been excluded and no timber cutting has taken place except incident to minor military projects. As a result of recent treatment, the cover in general, both overstory and understory, has greatly improved.

177. The non-Federal water supply areas, for many years, have been managed very satisfactorily from a flood and erosion control standpoint. Much of the land has been fenced; locked gates have excluded all forms of grazing and timber cutting. Some recreational use is available but such use does not constitute a major problem.

Management of national forest land

178. About 65 percent of the timberlands of the watershed constitutes a part of the Pike National Forest. Water is given primary consideration in the management of this area and in the utilization of its resources. Some timberland has been set aside exclusively for water supply purposes with no timber cutting or grazing permitted, whereas other areas are managed on a sustained yield basis; all timber is afforded protection from fire, tree insect pests, and tree diseases. Most denuded areas have been reforested with suitable species. Multiple use, including recreation, grazing, timber utilization, and wildlife management, is regulated in a manner to assure the perpetuation of the natural resources.

179. Several communities, including the city of Colorado Springs, are wholly or partially dependent on the national forest for municipal water supplies. Provision has been made for the protection and maintenance of these sources of both municipal and irrigation water by the inclusion of national forest land in water supply reservations and special use areas designated for this purpose. Grazing of domestic stock is already prohibited on 65 percent of the national forest and plans provide for the adjustment of use on the remaining 35 percent as conditions permit. The recreational and wildlife aspects of national forest lands are discussed at other places in this appendix.

Management of other patented timberlands

180. The remaining 41,579 acres, 27 percent of the total timberland, is almost exclusively in private ownership although it includes a few scattered State-owned tracts which have been managed somewhat the same as the private acreage.

Table 16. Extent of timber types by class of ownership, Fountain River Watershed, 1947

Class of ownership	Timber type				
	Conifer	Pinon-juniper	Aspen	Total	Percent
	Acres	Acres	Acres	Acres	
National forest	68,113	91	30,575	98,799	64.5
Military establishments	407	2,649	2,153	5,209	3.4
Non-Federal water supply areas	4,950	360	2,270	7,580	5.0
All other 1/	38,839	2,244	496	41,579	27.1
Total	112,309	5,344	35,494	153,167	100.0

1/ Largely in privately owned patented lands. Less than 2,000 acres in State ownership.

Table 17. Estimated timber volumes by important species and class of ownership, Fountain River Watershed, 1947

Class of ownership	Timber volume by species (M.B.M.)					
	Ponderosa pine	Douglas-fir	Engelmann spruce	Limber pine	All 1/ others	Total
National forest	23,164	40,210	9,059	7,001	1,428	80,862
Military establishments	555	-	-	-	-	555
Non-Federal water supply areas	2,127	1,815	429	186	59	4,616
All other inside national forest	3,747	3,198	756	327	104	8,132
All other outside national forest 2/	35,246	3,467	25	86	1,467	40,291
Total	64,839	48,690	10,269	7,600	3,058	134,456

1/ Includes bristlecone pine, lodgepole pine, blue spruce, and white fir.
2/ Largely in privately owned patented lands. Less than 2,000 acres in State ownership.

181. Of the total figure, about 15,178 acres are irregularly distributed throughout the national forest or in the vicinity of Woodland Park; 15,683 acres are within the Black Forest in the northeastern portion of the watershed; and the remaining 10,718 acres form a fringe of timbered land below the national forest boundary together with small acreages near Templeton Gap and in the southeastern part of the watershed.

182. Privately owned timberlands represent a wide range of conditions but in general they have been subjected to poor treatment and exploitation. Much of the area has been repeatedly cut over and heavily grazed by cattle and dude ranch horses. Those which have been grazed in conjunction with dude ranch operations although small in extent represent some of the most serious runoff and erosion conditions to be found on the watershed.

183. The timber stands at the lower elevations and in the Black Forest area are controlled largely by farmers and ranchers who include the acreage as part of the grazing range. Timber growth in those areas is very slow and is estimated to average 25 board feet per acre. The stands are relatively open and support a poor understory which is almost universally grazed. Unrestricted cutting, burning of litter and duff in an effort to secure a little sparse grass, and actual clearing of the underbrush for similar reasons, have left most of the stands in a poor condition from the standpoint of runoff retardation and erosion prevention. Heavy grazing use has prevented normal development of cover, and disturbed and laid bare the loose soil which erodes rather rapidly when exposed.

184. For the past few years, a farm forester has been working in the Black Forest under the terms of the Norris-Doxey Law. He has assisted in marking, marketing, and management of woodlands. As the result of his efforts, improved forestry management practices were installed on a limited number of farms and ranches. Unfortunately, this project has been discontinued due to lack of funds.

CHARACTER OF FARMS

Type of Farm

185. About 43 percent of the 396 operating units are livestock farms; 14 percent are crop farms; and the remaining 43 percent are part time, miscellaneous, and rural nonfarm units. Practically all units maintain livestock which contribute to farm income.

186. Until recently, the sale of dairy products was a major enterprise on one-fourth of all farms, however, in the past few years, there has been a shift from dairy to beef production. According to the 1945 U. S. Census, over one-half of the gross agricultural income was from the sale of meat animals, primarily beef. The current high price of livestock products has stimulated the demand for land and is encouraging the consolidation of small units.

187. Topography, soils, and rainfall restrict crop farming to the relatively narrow valley floor. Where irrigation farming is concentrated along the river between Colorado Springs and Pueblo, the principal crops are alfalfa, corn, truck crops, sugar beets, and small grain. Dryland farming is practiced on lands bordering the irrigated valley floors and in scattered tracts north and east of Colorado Springs. Corn is the

principal dryland crop with alfalfa, native hay, and small grain of secondary importance. A large portion of the cultivated land is operated by ranchers and used primarily to produce winter feed. There are less than 60 full-time crop farms in the watershed.

188. Seasonal recreational and industrial employment result in considerable part-time farming. There also is a desire on the part of many urban business people to live in the country. These people are not true farmers although they may have some plowed acreage and may keep a few head of livestock. Their holdings are classed as rural nonfarm. The influence of recreational interests, local market demands, and the desire to live in the country, is evident in the 90 part-time farms and about 40 rural nonfarm units. These factors have a tendency to create land values which cannot be supported by normal farm operators.

Size of Farm

189. The average size of farm unit is about 900 acres. However, one-fourth of the farms have only 80 acres or less; 32 percent range in size from 81 to 320 acres; 35 percent have from 321 to 1,920 acres; and 8 percent are in excess of 1,920 acres. Stock ranches are principally in the large size class and are scattered throughout the plains section of the watershed. Dairy and extensive crop farms make up much of the intermediate size farms and are generally located in the irrigated sections. The farms falling in the small class sizes are primarily intensive crop farms, part-time farms, or rural nonfarm units.

Farm and Crop Values

190. The total value of farm property in the watershed is estimated at $18,530,000 based on 1945 U. S. Census data. About

three-fourths of this investment is in land and buildings, one-fifth in livestock, and the balance in improvements and machinery.

191. The estimated value of all livestock and crops sold or used in farm households in 1945 was $5,687,400. One-half of the total value was in the form of livestock products sold: poultry, and poultry and dairy products accounted for 25 percent; crops sold made up 19 percent; and the remaining 6 percent was the value of products used in farm households.

Other Features

192. The farm mortgage debt situation has improved during recent years. Favorable conditions have enabled farmers to retire all or a large part of the farm indebtedness. Whereas in 1939, 38 percent of all nonpublic land was mortgaged, less than half that figure applies in 1947.

193. Tax delinquency is not now a major problem in the watershed. However, during prewar years, taxes on 20 percent of the land were paid by parties other than the owner. Income from sources other than land, favorable economic conditions, and interests of third parties are keeping delinquency low. At the present time, tax delinquency is negligible.

WATER SUPPLY

Irrigation

194. The jurisdiction of water rights in Colorado is vested in the State Engineer whose organization consists of division engineers and district water commissioners in charge of their respective areas. The portions of El Paso and Teller Counties in the watershed are in Water District 10, and of Pueblo County in Water District 14.

195. Use of water for irrigation is of great importance in the Fountain River Watershed but irrigation enterprises have suffered extensive losses. According to the U. S. Census of Irrigation, in 1939 Fountain River enterprises were capable of supplying 22,949 acres with water but only 14,460 acres were actually irrigated. Irrigation was abandoned on 8,204 acres between 1929 and 1939, a decrease of over 36 percent. Total investment in irrigation enterprises in 1919 was $965,287. During the following 10 years the investment decreased by $545,398 or 56.5 percent, an average annual decrease of $54,540.

196. The most logical factors operating in the watershed to explain the marked decline in both acreage irrigated and total investment in enterprises are:

a. Increasing costs of maintaining diversion works damaged by floods resulting in the abandonment of some ditches.

b. The character of stream flow is believed to have changed from sustained summer floods of moderate discharge, to erratic summer discharges with high peak flows of short duration followed by extended periods of very low discharge. Although total monthly summer discharge may be equal in both cases, under former conditions a larger percent of the flow was used in orderly applications to the crops whereas now there is excess water for short periods and a scarcity of water for long periods.

c. Flash floods wash out diversion structures and by the time they are replaced the flood flow has passed thus preventing the irrigational use of flood waters.

197. In 1947 approximately 15,000 acres were irrigated by direct gravity diversion of natural stream flow, release of water from storage reservoirs, and pumping. Unreliability of stream flow, together with current flood hazards, is stimulating the development of wells and pumping facilities in areas where ground water is available.

198. In addition to the irrigated land in the watershed, there are from 5,000 to 6,000 acres of irrigated land on the Arkansas River between Pueblo and John Martin Reservoir on the Arkansas River which are dependent on Fountain River water. Sediment problems are of major importance on these lands. Operators try to close gates and prevent the use of Fountain River water whenever it is in flood or high peak stage because of the undesirable silt content.

Domestic

199. There are 10 cities and towns within the watershed having a total population of about 50,000 partially or wholly dependent upon the watershed for their water supplies. Colorado Springs obtains its supply from catchment areas on the slopes of Pikes Peak, most of which are in the Fountain River drainage. The eight reservoirs comprising the system have a total storage capacity of 12,900 acre feet; four of these reservoirs with a capacity of 8,300 acre feet are in the watershed.

200. Water for industrial purposes is furnished almost exclusively by municipal systems. Stream pollution is not yet a problem since there is little waste from industrial plants. Colorado Springs constructed an activated slude sewage treatment plant in 1938.

201. The 400 farms in the watershed are dependent upon wells, springs, municipal water systems, or streams for both stock and domestic water. North of Fountain the domestic supply is derived largely from springs, streams, and shallow wells. The supply in this area is generally of adequate quality and sufficient quantity to satisfy the demand. South of Fountain the waters are in contact with Pierre shale and are of inferior quality.

Power

202. The city of Colorado Springs operates two hydro-electric plants in conjunction with its water supply system. The Manitou power plant has a capacity of 5,000 kilowatts. The Ruxton plant has a capacity of 1,000 kilowatts. Future development at a proposed Cascade site will add 1,000 to 2,000 kilowatts. Colorado Springs supplies power to nearby towns and to an area extending 70 miles eastward.

RECREATION AND WILDLIFE

203. The Colorado Springs-Pikes Peak area has been the center of a thriving tourist and recreational business for many years. Large amounts of both private and public capital have been spent for the development of the natural local attractions. The Pikes Peak Railroad and Highway, Garden of the Gods, Manitou Incline, Cheyenne Mountain, numerous dude ranches, and scenic drives attract thousands of visitors each year. The Colorado Springs Chamber of Commerce estimates that the tourist industry contributes 10 million dollars annually to the income of the watershed.

204. On the Pike National Forest, summer home areas have been developed and leased to individuals; camp grounds, and picnic areas have been developed and maintained for general recreational use; and scenic highways and horse and foot trails are provided and receive heavy use.

205. Prior to 1900, the stream channel and upland cover conditions favored high population of big game, beaver, game bird, fish and other wildlife. Although major habitat changes have taken place there still remains a variety of wildlife in the more remote and inaccessible areas, especially in the mountains.

206. The Pikes Peak State Game Refuge includes about 170,000 acres of the watershed, over half of which is on national forest lands. The refuge is largely closed to hunting and supports a very large percentage of the total game population of the watershed. It is estimated that there are about 1,500 mule deer and a few elk on and adjacent to the national forest. Forage for these animals is largely available in those portions of the forest closed to the grazing of domestic livestock. In addition, there are a few deer in the Black Forest area and about 150 antelope in the plains area. Because of the small number, the competition with domestic livestock is not a major problem.

FLOOD CONTROL ACTIVITIES OF OTHER AGENCIES

MUNICIPALITIES

207. The city of Colorado Springs in cooperation with the Works Progress Administration improved the Monument-Fountain channels through the city at a cost of $1,500,000. Improvement work consisted principally of concrete channels of a designed capacity of 50,000 c.f.s., the estimated peak discharge of the maximum flood of record in the locality. This improvement work is being maintained by the city of Colorado Springs.

208. In 1937 the city of Pueblo, cooperating with the Works Progress Administration, changed the channel of the Fountain River about 3½ miles north of its confluence with the Arkansas River at a cost of $152,500. This work consisted of channel straightening by excavating a pilot channel having a minimum width of 200 feet a portion of which was protected by hand-placed riprap. This improvement work is being maintained by the city of Pueblo.

FEDERAL AGENCIES

Corps of Engineers

209. House Document No. 186, 78th Congress, reports upon a survey of Fountain River by the Corps of Engineers in which the construction of the Templeton Gap floodway for flood control at Colorado Springs was recommended. This project has now been authorized and construction is under way.

Department of Agriculture

210. Several Department of Agriculture agencies are engaged in soil and moisture conservation activities within the drainage and portions

of their programs contribute to the alleviation of existing flood and sediment problems. It is estimated that annual expenditures of Federal funds by these various agencies will amount to $62,015 during the installation period for measures deemed of primary importance to flood or sediment control of which $4,414 will be for installations on Federal lands and $57,601 on non-Federal lands through cooperative programs with land operators.

211. While several agencies are active within the drainage the extent to which each contributes to flood and sediment control varies with the nature and location of its work.

212. The Forest Service administers the Pike National Forest and in its management stresses the importance of these lands from a flood control and watershed protection standpoint. Types of work currently being performed which contribute to flood and sediment control consist of tree planting, fire protection, road improvement, and range and timber management. In 1934-35 the Forest Service, through the Civilian Conservation Corps, constructed six flood control and debris dams on private land on Fountain Creek and its tributaries. These reservoirs have uncontrolled bottom outlets and capacities ranging from 5 to 25 acre feet. Although low in storage capacity, these reservoirs have effected some reduction in flash flows. The effectiveness of these dams has been greatly reduced due to lack of maintenance. However, the proposed program provides for cleaning the largest of the dams and other arrangements are being made that will allow cleaning of the remaining smaller dams restoring much of their original efficiency. In addition to the above, the Forest Service

has operated a cooperative Farm Forestry Project in and adjacent to the Fountain basin in the Black Forest area.

213. Technical assistance to develop and carry out conservation plans is furnished to farmers and ranchers who have organized soil conservation districts by the Soil Conservation Service. Three such districts have been established with a total area of 228,521 acres or 38 percent of the drainage basin and including about 75 percent of the farm or ranch operators.

214. With technical assistance furnished by the Soil Conservation Service the land operators are developing soil and water conservation plans and applying practices many of which contribute to the retardation of runoff and soil erosion reduction. Practices applied which are considered of primary importance to flood control objectives include: range improvement, range seeding, stockwater developments, terracing, diversion, contour farming, crop residue management, strip cropping, and land leveling.

215. In 1934-35 in cooperation with the Civilian Conservation Corps a project was established in the Templeton Gap area to demonstrate on-the-ground agricultural practices and structural treatment for soil and water conservation.

216. The Production and Marketing Administration through its Agricultural Conservation Program branch has been carrying on a conservation program in the basin by making direct aid available to land owners or operators for soil and water conserving practices. This program has resulted in the installation of many soil and water conservation measures. Practices considered of importance to the

alleviation of flood and sediment problems which have been put into effect consist of erosion control dams and ditches, terracing, installation of rock and brush dams, stock-water dams, establishment of fire guards, tree planting, fencing, riprapping of stream banks, pasture seeding, and grazing land management.

217. The Extension Service, through demonstrations, tours, farm visits, radio programs, newspaper articles, and 4-H programs, conducts educational activites for agricultural programs in the basin which result in the adoption of acceleration of soil and water conservation measures, some of which contribute to flood and sediment control. In various parts of the watershed, community planning committees have been established and flood control has been one of the problems considered by the committees.

218. Other agencies active within the watershed include the Farm Credit Administration which makes production and capital loans and the Farmers Home Administration which carries on its rehabilitation program and also makes production and capital loans to borrowers who enter into contracts involving farm management plans.

FLOOD AND SEDIMENT DAMAGES AND THEIR CAUSES

CAUSES OF DAMAGES

219. All damages caused by the action of flood water and waterborne sediment are the result of natural watershed factors conducive to excessive runoff and soil erosion, or induced factors brought about by the action of man, or through a combination of these two classes of contributing factors. In the case of Fountain River and its tributaries

both types of factors have contributed to the flood and sediment problem although the induced causes of floods are becoming increasingly important.

Natural Causes

220. Fountain River basin lies in the cloudburst zone of eastern Colorado and also receives precipitation from heavy general rains falling on large portions of the area so that floods probably were experienced prior to earliest settlement. High intensity summer thunderstorms cause rapid rises in stream flow and flash floods during the season of normally low flows. The topography and slope of the land are such as to encourage rapid concentration of runoff in the area above Fountain. Below Fountain, the factors favoring concentration are offset by the long narrow shape of the basin.

221. Records show that the relation of surface runoff to storm rainfall is moderately high. Although the mountainous portion produces much more water than the plains section, the reverse is true insofar as the production of floods is concerned. Lower inherent infiltration rates and higher rainfall intensities on the plains result in more frequent damaging floods. Soil conditions on the plains are largely responsible for the low infiltration. An important characteristic of soils developed from the Dawson formation, about 26 percent of total watershed area, is that they become very compact when dry and thus have lower infiltration rates than are usually found on soils having similar textural ranges. An additional 30 percent of the watershed is occupied by soils having clay subsoils which slow the downward percolation of water. Finally, most of the plains soils are subject to puddling and sealing of the surface layer.

222. Another natural factor contributing to the flood problem is the occurrence of periodic droughts which reduce the vegetative density, increasing runoff, and water and wind erosion.

Induced Factors

General

223. Shortly after settlement, induced factors began to augment the natural flood causes. These induced factors rapidly increased in importance until at present they are the major causes of damage. Settlement brought about the development of and encroachment upon the flood plain thereby continually increasing damageable values. Whereas earlier floods consisted of relatively clear water and moved slowly in a wide unrestricted flow over native meadows and natural grass waterways, more recent floods are restricted by roads and numerous channel constrictions, and pass through eroded gullies and over raw slopes causing extensive water and sediment damage to bottomland developments and improvements. Man-caused changes in land use and treatment, especially on sloping lands, have greatly aggravated the flood flows.

Range land problems

224. Excessive and uncontrolled use of the forage resource was one of the first problems and continues to be of major significance in the plains area and on much of the individually owned mountain lands. Carrying capacities and watershed protection values have continued to decline not only because of excessive numbers of domestic livestock but also because of extended grazing seasons which, in many instances, are yearlong. The original overuse depleted the cover to such an extent that now a much smaller number of stock keep the range

in poor condition. Low market prices for beef cattle in the 1930's coincided with a series of drought years. As a result, cattlemen whose ranges were already overstocked did not materially reduce the number of livestock during the drought periods because of low prices, and the vegetation was injured seriously. Recent improvement in markets and a more favorable climatic cycle have provided some relief to the range. Nevertheless, the range is still not able to hold the soil in place and both sheet and gully erosion are accelerating. Undesirable grasses and weeds have invaded many areas to the detriment of the better species. The thriftiness of those desirable grasses which remain has been so reduced as to make them ineffective in stabilizing the soil mantle. Reductions in plant density and absence of litter have made the soil compact and hard thereby permitting the rapid drying of the surface and reducing the absorption and percolation of water. Careful management together with conservation practices are necessary to check accelerated erosion and to enable the range lands to regain their potential productivity.

Cropland practices

225. Very soon after settlement the most productive alluvial lands were rapidly converted to cropland. Riparian vegetation was promptly removed in order to extend the fields as much as possible. Little or no provision was made for the disposal of sidehill drainage which became a greater problem year after year as the vegetation on the slopes became less effective in holding back water and sediment. At the present time, the bared streambanks erode rapidly and many acres of valuable bottomland are lost annually through streambank

cutting. As the channels develop and grow deeper and wider, subsurface drainage lowers the water table on adjoining land and irrigation by direct diversion becomes more difficult. At the same time, sterile sediment from adjoining roads and hill lands is deposited on many fields.

226. As the pressure for cropland became greater, additional sloping land was brought into cultivation without adequate provision for the conservation of the soil. Recent market conditions brought about the cultivation of former range land which is not adapted to cropping practices. As a result, much wheat, corn, and other crops are being produced either on hill land unsuited for such production or under soil depleting practices. More than one-fourth of the dry cropland acreage should be reseeded back to grass.

Timberland problems

227. In the Black Forest and other timbered areas at the lower elevations, the major induced problems are exploitative logging, unregulated grazing, and uncontrolled burning. These woodlands are so accessible and located so close to agricultural, mining, and industrial areas that practically every acre has been cut over three or more times, each cutting being more destructive than the previous one. It is a rare stand which consists of trees in excess of 12 or 14 inches in diameter. The demand for mine props and fence posts has resulted in the removal of many 4- and 5-inch trees. Logging is frequently followed by fire which has scarred most trees and destroyed much reproduction. Fire is used extensively as a means of disposing of slash, litter, and duff with the hope that a few blades of grass

will appear. Livestock promptly feed on the woodland surface cover and when seeking protection from the weather congregate in the woodland areas. The resulting trampling causes disturbance of the surface and encourages accelerated erosion.

228. In the mountainous timbered areas, a wide range of conditions exist. The problems on the Federally owned land and watershed protection areas under non-Federal ownership are relatively minor. A small amount of grazing trespass occurs on the unfenced lands. Areas of intensive recreational use are subject to rapid runoff and erosion but such conditions are very limited in extent, and do not contribute materially to the over-all problem. In the past, forest fires were very destructive and large areas were burned over. Most of the burned areas have been planted or have recovered naturally although there are a few areas remaining where site stabilization is not yet satisfactory.

229. Problems on the mountainous timbered areas which are not devoted to protection purposes are more acute although the acreage involved is less extensive. In many respects, these lands are subject to the same abuses as are the timberlands of the Black Forest. Timber cuttings are frequently made for the construction of log cabins, guest cabins, out buildings, and corrals. Fire is not uncommon. Seasonal concentrations of saddle horses in and adjacent to dude ranches, together with some cattle grazing, has all but eliminated reproduction and surface vegetative cover in small areas. Many active gullies may be found on privately owned lands where runoff and erosion are accentuated by the steep slopes and unstable granitic

soils. The drainage area above Manitou Springs with inherently unstable soils from which the cover has been removed by overgrazing, timber cutting, and in some cases cropping, together with poor location and construction of many roads has made this a critical problem area.

Other

230. Many miles of roads have been constructed without sufficient regard to cut and fill slopes and drainage facilities. In an effort to maintain alignment, many water disposal problems have developed. Bridges and culverts have proved inadequate. Back slopes and berms are not stabilized and in many instances road ditches have developed into deep gullies which have built up large sediment fans in the natural drainageways.

231. Flood damage to urban property is in no small measure due to channel restrictions and encroachments together with the development of unprotected flood plain areas. This is especially true in the vicinity of Manitou Springs where steep slopes have limited the number of suitable development sites and where the bottomlands and overflow areas are highly developed.

FLOOD AND SEDIMENT DAMAGES

General

232. It is assumed that existing and authorized flood control improvements will prevent all future damage to Colorado Springs and Pueblo from flood flows not in excess of designed capacities of the channel, i.e. 50,000 c.f.s. at Colorado Springs and 30,000 c.f.s. at

Pueblo. Therefore, potential future damage to these two cities has not been included in the development of expected future damages as set forth in this report. However, it should be pointed out that future flood flows in excess of designed capacities will cause damage at these points and any reduction in peaks of such flows brought about by the installation of flood control measures on the watershed will be reflected by a decrease in the potential damage.

233. The evaluation of future damages, if no program is adopted, is based upon the assumption that a series of floods will occur in the future, in manner and magnitude similar to those that have occurred in the past and the damages they cause will be similar in character although mitigated in some respects by changed conditions along the streams and flood plains. Evaluation is made on the basis of 1947 prices. Past recorded damages were adjusted to reflect current prices, and are expressed in terms of annual losses or damages. (See table 18)

Agricultural Damages

234. Damage to agriculture, exclusive of sediment damages to irrigation systems, amounts to almost half of the $300,500 average annual flood and sediment damage. A substantial portion of the agricultural damage is in the form of lost production due to land destruction from bank cutting. During the past 80 years, 7,325 acres of land have been lost for an average annual loss of 92 acres; 4,138 acres of the total were located along the main stem and 3,187 in the major tributary bottoms. The present rate of loss is probably in excess of the 80-year average figure because the cutting action has been accelerating in recent years. The damage from the loss of 1 acre is represented by

the value of the annual production to the economy of the watershed if destruction had not occurred. Unless corrective measures are taken, it is expected that the future loss will be equal at least to the past loss. Based on a normal distribution of crops, and average yields and prices, during the first year the loss would amount to slightly more than $25 per acre for each of the 92 acres which would be lost. In each succeeding year, the loss would be accumulative at a rate equal to the loss during the first year. Over a 100-year period, the average annual loss would amount to $116,500.

235. Estimates of damage to agriculture from overbank flooding on the main stem are based largely on the 1921, '32, '35, and '36 floods. Field studies indicate that damages of this character on the tributaries occur much more frequently. For both main stem and tributary damage areas, it is estimated that damage to crops, buildings, fences, and other agricultural works amount to $31,500 annually.

Public Property and Utilities

236. Based on the records of the railroad companies, the average annual flood damage experienced by all railroads in the Fountain River watershed is estimated to be $22,500.

237. A large percentage of the 560 miles of roads in the watershed are subject to erosion and floodwater damage. Principal damage results from the lower construction class type of roads with their substandard cut and fill slopes, and improper drainage facilities. In most cases, damage is reflected in increased maintenance charges. The average annual maintenance attributed to flood damage varies from

Table 18. Summary of average annual flood and sediment damage, Fountain River Watershed, 1947

Type of damage	Value	Portion of total
	Dollars	Percent
Agriculture		
Destruction of land by bank cutting	116,500	
Loss of crops, buildings, fences, etc.	31,500	
Total	148,000	49.2
Public property and utilities		
Railroad	22,500	
Road	27,500	
Bridge	16,500	
Total	66,500	22.1
Urban	16,200	5.4
Indirect	32,600	10.9
Irrigation systems		
Canal and ditch sedimentation damage in Fountain River drainage	8,000	
Canal and ditch sedimentation damage between Pueblo and John Martin Reservoir	15,300	
Total	23,300	7.8
Reservoirs		
Sedimentation damage to Fountain River reservoirs	3,500	
Sedimentation damage to John Martin reservoir	10,400	
Total	13,900	4.6
Grand total	300,500	100.0

10 percent of the yearly maintenance cost of the better type roads to as much as 90 percent in the case of lower class roads. Based on available county records, opinions of road commissioners and other officials, and discussion with Forest Service personnel, it is estimated that the average annual damage to roads in the Fountain River watershed is $27,500.

238. Damage to road bridges is widespread. In some cases, sediment deposits have reduced capacities to such an extent that bridges are washed out by only minor floods, whereas in other instances degradation and lateral widening have undercut supports and bridges have collapsed. In the latter cases, bridges are not only replaced but new spans and approaches must be added. According to the most reliable estimates, the aggregate damage to bridges amounts to about $16,500 annually.

Urban Flood Losses

239. Most of the urban property which is not adequately protected by existing or authorized flood control works is located in and adjoining Manitou Springs on Fountain Creek. Other than loss of life and important intangible damages, it is estimated that flood and sediment losses in urban areas amount to $16,200 per year.

Indirect

240. In addition to the direct damages cited, indirect damages also occur resulting from loss of production, loss of revenue due to interruption of business, and added costs of rerouting traffic. Loss estimates are based on data gathered during the course of the survey and studies of this type of damage on other similar watersheds.

This damage occurs largely within the urban, agricultural, road, bridge, and railroad damage categories and is estimated to amount to $32,600 annually.

Irrigation Systems

241. Fountain River sediment is deposited in irrigation canals and ditches within the watershed and also in systems along the Arkansas River between Pueblo and John Martin Reservoir. In both cases the sediment must be removed from the systems at considerable expense.

242. Actual costs for removal of sediment from irrigation systems within the watershed were obtained from a representative number of officials and owners of canals and ditches. Based on such estimates, the average annual sediment removal cost amounts to about $8,000 per year.

243. Sedimentation studies show that of the 477 acre feet of sediment produced from the Fountain River at Pueblo, 270 acre feet are deposited in the Arkansas River channel and flood plain, 75 acre feet stop in John Martin Reservoir, 32 acre feet pass through the reservoir and 100 acre feet enter irrigation systems between Pueblo and the reservoir. About one-half the material entering the canals is deposited in the canals and ditches whereas the other half is deposited on the land or in waste ways. At an average cost of 19 cents per cubic yard for sediment removal, total costs of removing deposits of Fountain River sediment, 50 acre feet, from the irrigation systems averages about $15,300 annually.

Reservoirs

244. Damages from sediment deposits in reservoirs amount to almost 5 percent of the total losses due to floods and sediment. There are 48 reservoirs with a total capacity of over 14,000 acre feet in the watershed. They are of varying sizes and designed for many purposes including domestic water supply, power, irrigation, recreation, and other uses. The 1947 replacement cost for these reservoirs is in excess of $700,000. Previous studies indicate that the annual sedimentation rate is at least 0.5 percent. Based on replacement cost, the annual damage due to sedimentation of reservoirs on the Fountain River Watershed totals about $3,500.

245. As pointed out above, 75 acre feet of Fountain River sediment is deposited annually in John Martin Reservoir, on the Arkansas River (16). Based on the operational schedule of the reservoir and nature of the sediment, it is assumed that 30 acre feet of the annual 75 acre feet of sediment deplete flood control storage and 45 acre feet will be charged against irrigation storage. Flood control storage lost through sedimentation is evaluated in terms of the estimated benefits per unit of storage capacity which in the case of this reservoir is estimated to be $0.54 per acre-foot annually. Computed over a 100-year period, the average annual value of damage resulting from Fountain River sediment in the flood control pool amounts to $800. Damages to the irrigation pool are based on the difference in net income per acre from irrigated land as compared to dry land divided by the number of acre feet of water used to

produce a crop. Evaluated over 100 years the 45 acre feet of Fountain River sediment deposited yearly in the irrigation pool gives an annual damage of $9,600. The combined damage equals $10,400 annually.

Nonevaluated and Intangible Damages

246. Many damages have occurred that are either intangible or difficult to evaluate. In the aggregate, they probably total as much as the tangible losses. Perhaps the most important of the nonevaluated damages is the enormous loss of life that has occurred as a direct result of floods. Past floods have caused 196 deaths, including 78 lives lost in Pueblo as the result of the 1921 joint flood on the Arkansas and Fountain Rivers.

247. Local residents with experience of past floods are apprehensive of future floods. People are forced from their homes and the destruction or impairment of domestic water supplies and sewage disposal facilities increases susceptibility to sickness and disease. Lands adjacent to the stream beds that might have been used as residential or business sites, or for intensified crop production are relegated to lower value use. Irrigation has been abandoned on several thousands of acres because of excessive maintenance costs of diversion structures and insufficient or sporadic water supplies. Loss of topsoil with its high concentration of plant nutrients through sheet and gully erosion represents an enormous loss. Flood damaged roads constitute traffic hazards that endanger the lives of motorists. Fine sediment deposits over irrigated fields in most cases lower the

productive value of the land and increase cultivation costs. Ill effects of sediment deposits along the Arkansas River often take the form of swamping. Possible reduction in summer tourist trade as result of floods is another intangible damage. The effect of floods and sediment on fish life, game, recreation, and aesthetic interests is well known.

PLAN OF IMPROVEMENT AND EFFECTS OF PROGRAM

RECOMMENDED MEASURES

General

248. The proposed watershed program for reducing surface runoff, retarding waterflow, and preventing soil erosion, and thereby reducing flood and sediment damages, contemplates measures on cultivated, range, and woodland areas and for solving special problems related thereto. The acquisition of 4,880 acres on the critical drainage area above Manitou may be necessary in order to install and maintain measures which are required for the adequate protection of downstream areas. Terraces, grassed waterways, strip cropping, and residue management are proposed for cultivated lands. Terraces and reseeding will be applied to croplands in need of retirement. Adjustments in period of use and number of livestock are recommended for range lands. Good range management, fencing, and proper timber practices, including restricted grazing, fire protection, and conservative cutting, are essential to the success of the program.

249. Bank protection supplemented by plantings and fencing is proposed for prevention of further destruction of valuable bottomlands.

Special measures are recommended for the control of road damage. Also, it is proposed to install a network of flood detention dams, each with a capacity of from 1 to 10 acre feet. Dams will be located in upper reaches of natural drainageways and will temporarily store flood waters as well as arrest gully development. Where physical conditions permit, water spreading areas will be developed as a supplement to the control of excessive surface runoff. Technical services will be furnished for installing and in some cases maintaining measures and practices.

250. The program recommendations included fall into two main groups. These are: Group 1 - land treatment and related measures, and Group 2 - other measures not directly associated with land treatment but needed to achieve the objectives of the program for runoff and waterflow retardation and soil erosion prevention. Program coordination and evaluation are considered separately because they apply to the installation of both groups of measures. The quantities of the measures included in the program are over and above those which will be installed under going programs of all Federal agencies and local organizations during the installation period assuming that the present rate of accomplishment will continue in the future.

Land Treatment and Related Measures

Reseeding

251. About 5,220 acres of privately owned dry farm land now in crops should be retired to grass. To aid in the successful establishment of adapted grasses, this acreage should be treated first with pasture dikes or diversion structures. The need for reseeding

existing range land is not great since evidence on the ground points to the satisfactory natural recuperative ability of the range when under good management and conservative use.

Terraces

252. In addition to the 5,220 acres of cropland which should be terraced and reseeded to grass, there are 17,053 acres of dry farm land requiring 260 miles of terraces and 30,000 acres of non-Federal range land on which 1,458 miles of terrace dikes and diversions should be constructed. On these areas surface runoff is causing lateral bank sloughing and encouraging the development of upland step-like headcuts.

Reforestation

253. Although many acres have been planted with trees in the mountainous portion of the watershed, there still remain some scattered areas which should be planted in the interest of site protection and runoff reduction. Some of these areas are on very steep slopes and in some instances form parts of old burns which have not recovered from past fires. Some of these lands are immediately adjacent to major streams and reservoirs, and should support a good tree cover. In the aggregate, about 3,260 acres should be reforested. Of the total, 1,970 acres are national forest land and 1,290 acres are in private ownership within and adjacent to the national forest. In addition, fire protection should be intensified on some 42,000 acres of privately owned woodland.

Fencing

254. About 90 miles of fence are needed in order to restrict and regulate grazing and restore desirable cover conditions on the area of privately owned woodland.

Road Improvement

255. Improvements will consist of stabilizing about 25 miles of raw cut bank and fill slopes, sloping and seeding about 900 acres of raw bank to suitable grasses, installation of some 10 miles of interception ditches and 25 miles of spreading ditches to cut down the erosive power of the floodwater and construction of about 1,000 borrow ditch checks. In addition, abandoned roads will be treated or obliterated.

Water spreaders and diversion structures

256. In areas not adapted to flood detention dams and where conditions favor water spreading, there will be constructed about 377 water spreaders and diversion structures. These structures will serve essentially the same purpose as the small dams and will be more common in the southern portion of the watershed where opportunities for spreading water are greater and where acceptable small dam sites are less common.

Work plans

257. Following action authorization, it will be necessary to prepare detailed work plans for the purpose of determining specific action on a year by year basis for subwatersheds. Such plans will be used for preparing annual budgets and work programs.

Technical services and educational aid

258. Technical services must be provided to prepare farm plans, provide advice to range and woodland owners and devise means to insure the adoption of the recommended measures. For dry farm land it will be necessary to lay out and supervise installation

of terraces and diversions and in addition it is recommended that strip cropping, contour farming, crop residue management, and light application of barnyard manure be practiced. These practices will help in the maintenance of the terraces, increase the absorptive capacity of the soils, and increase crop yields. The cropland reseeded to perennial grasses must be protected from grazing for about 2 years; then it must be used conservatively, its grazing capacity being dependent on the density of the stand and amount of forage produced during any one growing season. Current technical services and aid in the application of measures on irrigated lands except for stream bank protection is adequate to meet flood control objectives.

259. On range lands, conservative use of the forage resource is recommended. Such use will permit the vegetation to recuperate and exert greater influence in binding the soil in place and increasing its absorptive capacity. Regulated use is also essential to the successful operation of terraces and diversions and other recommended structures. The adoption of a system of grazing such as deferred and rotation or alternate use will prove helpful in increasing plant vigor and its ability to withstand grazing use and droughts.

260. Those lands which are devoted to timber growth should be managed in such a manner that maximum watershed values are provided and adequately protected. On privately owned land, selective cutting should replace the the present practice of indiscriminate and clear cutting. On logging operations, slash should be placed in gullies and old logging roads, to retard runoff and help stabilize

the soil. More consideration must be given to reproduction in an effort to secure uniformly dense stands; this is especially desirable in the Black Forest area. Fire must be prevented and controlled on all private holdings so that proper litter and humus development may take place. Grazing use should be restricted and regulated because of the inferior quality and limited amount of forage now being produced and also because the greatest value of these lands is for production of timber.

261. In addition to the above services and aid more intensive educational assistance will be required to inform private land operators of the program and its application and to assist in obtaining the cooperation of these operators in applying and maintaining program measures especially in those areas where farmers or ranchers are not participating in the phases of going national programs which contribute to flood control.

262. To provide these technical services and educational aid for the land treatment measures an estimated $171,300 will be required of which $23,700 is for educational aid.

263. Improved management practices on private lands will be brought about largely by the owners themselves with aid in the form of technical advice and, for some measures, direct aid payments, furnished in cooperation with Federal agencies.

Other Measures

Protection of Manitou Springs and vicinity

264. In order to prevent future damages to the Manitou Springs area and remove the present threat to human life, it is recommended that a plan which utilizes water and sediment detention structures and channel rectification be adopted.

265. The protection plan calls for the construction of one debris dam on Crystal Creek, one on Black Creek, and two in Williams Canyon. These dams should have a capacity of from about 20 to 30 acre feet each. In addition, the largest existing debris dam on Fountain Creek upstream from Manitou Springs should be cleaned and otherwise repaired. The mile of the Cave of the Winds road up Williams Canyon should be abandoned and in its place the Serpentine Road should be widened for 2-way traffic. Channel improvements in and adjacent to Manitou Springs will be made on about 2,690 feet of Williams Canyon, 2,130 feet of Ruxton Creek, and on 12,630 feet of Fountain Creek. These improvements include removing of restrictions, increasing capacities, providing freeboards, increasing wall heights, deepening channels, realigning bends, constructing grade weirs, protecting banks, constructing improved channels through critical areas, and similar measures.

Flood detention dams

266. In order to overcome some of the natural as well as induced causes of floods, a network of small dams for the temporary detention of flood waters is recommended for the plains portion of the watershed. On an average, each section of land will have from 1 to 10 of these dams, involving a total of about 10,000 cubic yards of fill and detaining a total of about 20 acre feet of flood water per section. Each

dam will have an outlet pipe of about 18 to 24 inches in size through its fill, and a dead storage of about 5 percent of the reservoir capacity. Whenever possible, they will be located in grassy swales above headcuts and will be provided with suitable discharge waterways. It is estimated that about 2,803 dams are required.

Streambank stabilization and revetments

267. Between Pueblo and Colorado Springs and upstream towards Manitou Springs, streambank erosion is prevalent, especially on the outside of the river meanders. Streambank erosion goes on during low flows as well as during flooding and the need for protection is almost continuous. The program provides for treatment of 13 miles of channel. Treatment of 10 miles will include such items as cabled trees and plantings with the remainder requiring tetrahedrons, and rail fences assisted by plantings.

Road improvement

268. The proposed improvement program will consist mainly of correcting faulty drainage structures and installing additional supplemental structures. Many of the existing bridges and approach roads will be raised for greater headroom. The specific measures include the resetting or installing of 840 culverts, raising, resetting, or replacing 50 bridges, and installing 2 miles of curbs and revetments.

Technical services

269. The selection of suitable sites for structures and sound construction practices are essential to satisfactory performance of improvements with reasonable maintenance cost. Engineering services in the amount of $179,000 is provided for site selection, design,

and construction of detention dams and streambank stabilization structures. For other structural measures such services have been included in the original unit costs in accordance with accepted engineering practice for similar work.

Program integration

270. The installation and maintenance of the complete flood control program for the drainage basin, including both vegetative and engineering features, will require the active participation and cooperation of many groups and individuals, both public and private. Over-all coordination and leadership will be provided to insure proper balance of the program.

271. Coordination activities will include, in part: preparation and procurement of agreements and memoranda of understanding; provision for uniformity in preparation of standards, designs, regulations, and reports; maintenance of proper interrelationships between measures; promotion of cooperativeness; checks of compliance by various agencies; and preparation of recommendations to insure lasting flood control benefits.

Program evaluation

272. With the initiation of the watershed improvement program, it will be necessary to measure its quantitative effects of runoff and stream flow on representative streams in order to ascertain the adequacy of the measures and to determine modifications needed for adequate watershed protection. The designed measures will serve as measurements or gages of the effects taking place on the watershed such as reduction of sediment loads, reduction in rates of soil deterioration, and effects upon stream discharge.

273. In connection with channel and streambank protection works, it will be necessary to test alternate means and methods of installing various works so that the best and most economical combination of measures may be adopted.

Miscellaneous

274. In order to accomplish the flood control objectives, it is highly desirable that action already underway on the Pike National Forest to acquire small interior holdings as they become available at reasonable prices be stressed. ~~Currently speculative recreational values are a definite handicap to acquisition of these lands. In this respect the use of receipts money through a Receipts Act would be desirable~~.

ESTABLISHMENT OF THE PROGRAM

275. It is recommended that the flood control program be carried out through organizations such as soil conservation districts, flood control districts, the Federal and state Forest Services, and other local, county, and state groups under coöperative agreements satisfactory to the Secretary of Agriculture.

276. It is further recommended that a 10-year period be considered for establishing the measures.

SOME BENEFITS AND EFFECTS OF THE PROGRAM

Flood Reductions

277. Infiltration rates were calculated from studies in or near the watershed. The effects of the program on reducing flood peaks was estimated on typical tributary watersheds and expanded to the remainder of the watershed. The calculated infiltration rates as determined from the sample tributaries are presented in table 19.

Table 19. Present and future infiltration rates, sample tributaries, Fountain River Watershed

Youngs Hollow					Kettle and Pine Creeks				
Land use	Soil group	Area in acres	fc (in./hr.) Present	fc (in./hr.) Future	Land use	Soil group	Area in acres	fc (in./hr.) Present	fc (in./hr.) Future
Pasture	2	8,525	.74	.82	Pasture	1	3,603	1.22	1.63
Pasture	3	7,033	.45	.50	Pasture	4	11,848	.82	.90
Pasture	4	140	.82	.90	Cultivated	4	716	.77	1.12
Pasture	8	4,129	.45	.50	Pasture	5	912	1.00	1.10
Pasture	7	4,134	.50	.67	Cultivated	5	80	1.35	2.00
Cultivated	7	301	.93	1.35	Pasture	8	19	.45	.50
Average			.57	.65				.91	1.08

278. Design storms on these typical tributary watersheds produced the precipitation excess or volume of surface runoff shown in table 20.

Table 20. Surface runoff volume, Fountain River Watershed

Runoff	Storms on Youngs Hollow 1.50	2.00	2.50	Storms on Kettle & Pine Creeks 1.50	2.00	2.50
		Inches			Inches	
Present	.92	1.38	1.65	.72	1.16	1.35
Future	.87	1.32	1.59	.63	1.05	1.22
Reduction	6%	5%	4%	12%	11%	10%

279. The effect of a single detention dam (see table 21) with a capacity of 20 acre feet per section is shown in table 22. The average reductions of floods from design storms, shown in table 23 is about 44 percent over a 50-year period.

Sedimentation Reductions

280. The program, when fully installed, will bring about a 50-percent reduction in sediment originating from surface erosion. This estimated reduction was determined from an analysis of the sample tributaries and after giving due consideration to: (a) the relatively high sediment production rates in the southern plains as compared to the balance of the watershed; (b) the trap efficiency of the detention dams which varies with the nature of the sediment; and (c) the kind and amount of other treatment measures.

281. Both upstream and channel works will be effective in reducing the amount of sediment originating from bank cutting. The reduced peaks brought about by the program and the mechanical channel structures will be most effective in preventing bank cutting from minor floods with less effectiveness in the case of major floods. Averaging all floods over a period of years, the entire program is expected to reduce the amount of sediment produced from bank cutting by 65 percent.

282. Of the 477 acre feet of sediment passing Pueblo annually, it is estimated that about 205 acre feet come from surface erosion and 272 acre feet from bank cutting. By applying the above percentage reductions to these figures, the over-all average annual reduction of sediment will amount to about 58 percent. The anticipated reduction

Table 21. Typical detention dam, Fountain River

Stage	Detention storage		Stage 1/	Spillway discharge	Stage	Outlet discharge 24 inches
Feet	Cu. ft.	A.ft.	Feet	c.f.s.	Feet	c.f.s.
1	3,000	0.07	0.5	30	1.0	15
2	8,000	0.18	1.0	80	2.0	22
3	20,000	0.46	1.5	155	3.5	29
4	34,000	0.78	2.0	240	7.5	42
5	56,000	1.28	2.5	335	10.0	48
6	86,000	1.98	3.0	440	12.0	53
7	128,000	2.94				
8	180,000	4.13				
9	240,000	5.50				
10	310,000	7.10				

1/ Above spillway stage of 10 feet, average of two existing dams (Dickson and Blake).

Table 22. Flood reductions on typical drainage area with detention dams, Fountain River Watershed

Sample tributary	Storm frequency	Flood peak		
		Present	Future	Reduction
	Years	c.f.s./sq.mi.	c.f.s./sq.mi.	Percent
Youngs Hollow	10	1,150	550	52
	25	1,750	1,300	26
	50	2,100	1,750	17
	max.	2,800	2,700	2
Kettle and Pine Creeks	10	900	350	61
	25	1,450	800	45
	50	1,700	1,100	35
	max.	2,650	2,500	4

Table 23. Average flood reductions, Fountain River Watershed 1/

Storm frequency	Flood peak		
	Present	Future	Reduction
Years	c.f.s.	c.f.s.	Percent
10	6,200	2,700	57
25	9,600	6,200	35
50	11,400	8,400	26
Max.	66,000	64,000	3

1/ Average floods from Youngs Hollow and Pine and Kettle Creeks or 32.5 square miles of tributaries.

in sediment from surface erosion is substantiated further by the data presented in the following paragraph.

Sediment Transporting Capacity

283. After installation of the program future floods will have lower stages and velocity and therefore will have less sediment transporting capacity. The total sediment load of Fountain River since 1941 has been sampled by the Corps of Engineers near Fountain and Pueblo. The relation ($S=KQ^{1.4}$) between sediment load (S) and discharge (Q) provides a basis for estimating the relative transporting capacity of floods in the future as shown in figures 12 and 13. These reductions, shown in table 24, average about 50 percent over a 50-year period.

Table 24. Sediment transporting capacity, Fountain River

	Frequency			
	10 yr.	25 yr.	50 yr.	Max.
	Percent	Percent	Percent	Percent
Flood peak reduction	57	35	26	3
Transporting capacity reduction	68	47	35	6

Benefits

General

284. The future improved hydrologic conditions of the watershed resulting from installation of a remedial program will be directly reflected in lessened flood and sediment damage. These benefits will accrue from a reduction in the magnitude and frequency of floods and

by decreased erosion which produces the damaging sediments. Land treatment and related measures including reseeding, terracing, tree planting, and improved management practices will stabilize the soil and improve plant cover resulting in higher infiltration rates and decreased erosion. By reducing sedimentation they will also have an important function in extending the life of structural measures and reducing maintenance costs. In addition, conservation benefits resulting from increased productivity will be realized and the overall effect will be of a permanent nature.

285. Other complementary measures, structural in type, will result in creation of temporary surface storage, stabilization of streambanks, improvement of roads and protection of urban areas and irrigation developments. These measures will have an almost immediate effect in reducing flood and sediment damage and will afford relief until the land treatment measures have become fully effective.

286. The original hydrological analysis was based on the difference in watershed conditions and their effect on flood flow and sediment production with and without a remedial program and without deducting going program accomplishments of other agencies as they affect hydrologic conditions. However, measures of primary importance to flood control objectives have been excluded from the program recommendations herein in amounts expected to be accomplished during the installation period by going programs. Proportionate benefits resulting from these excluded measures have been deducted from total benefits so as to reflect an estimate of expected benefits attributable to the program outlined in this report.

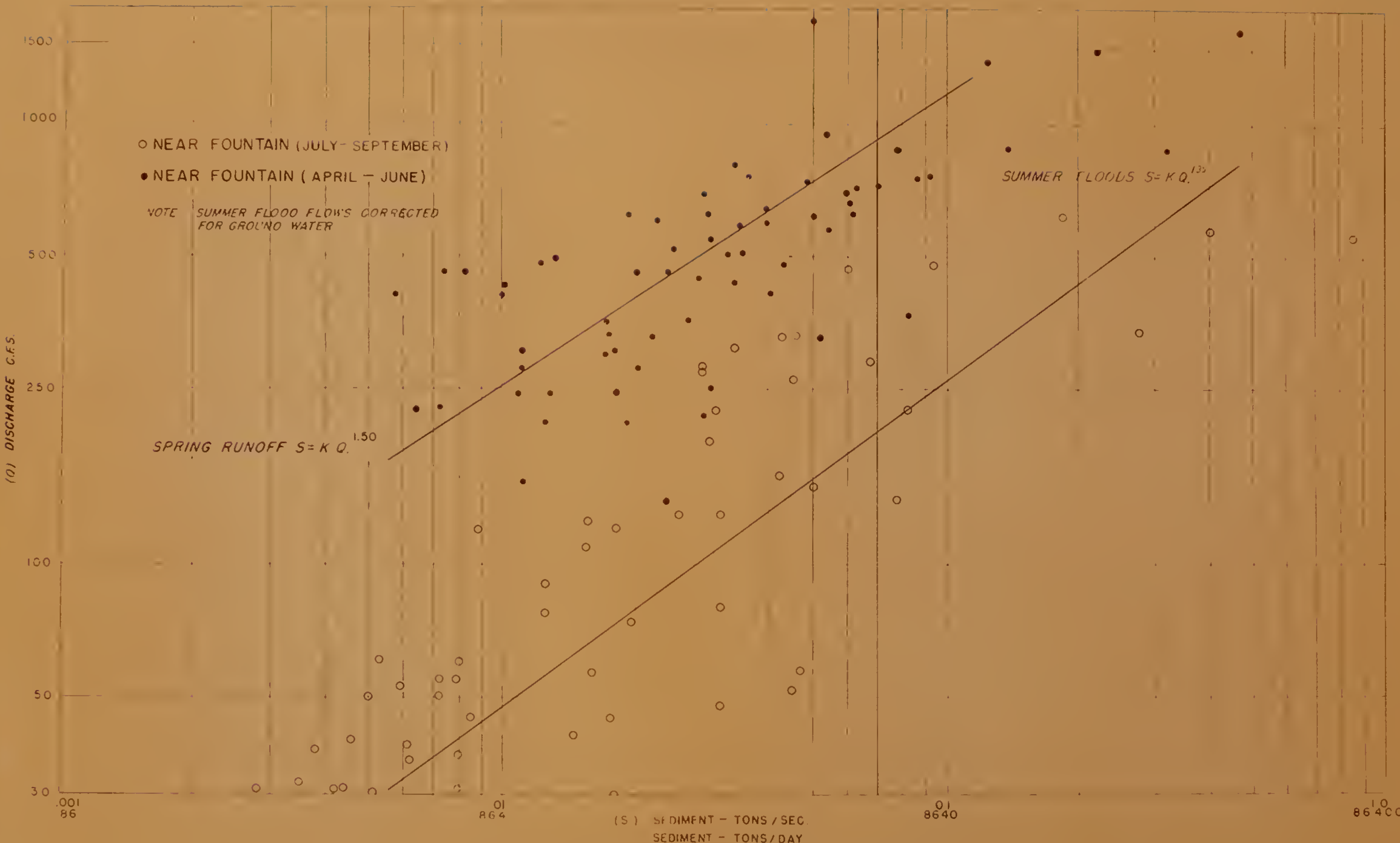

FIGURE 13 SEDIMENT VS DISCHARGE
FOUNTAIN RIVER WATERSHED COLORADO 1941-1945

287. For ease of discussion, the benefits from reduction in flood and sedimentation damages are grouped under six broad headings: agriculture, roads and bridges, railroads, urban, indirect, sedimentation within the Fountain River watershed, and sedimentation along the Arkansas River. These benefits are summarized in table 27.

Agriculture

288. A substantial portion of benefits expected to accrue to agriculture will be in the form of reductions in the loss of land from streambank cutting. Installation and adequate maintenance of mechanical structures such as stream bank protective works, small detention reservoirs, water spreaders, and drainage control sturctures will be immediately effective in reducing peak flows and sediment rates and will reduce loss of land from streambank cutting. Reductions in peak flows and sediment rates accomplished by the mechanical structures will enable the reestablishment of protective vegetative cover by natural and artificial means along streambanks and on denuded areas of watershed slopes. After a reasonable length of time the vegetative improvements are expected to further reduce damages to land. Within 20 years after the program is installed, damages to land will be reduced from approximately $116,500 annually to $40,800 resulting in an annual benefit of $75,700. Some of these benefits will occur almost immediately after installation but for purposes of this report the benefits are computed at the end of the 20-year period.

289. The above described effects of the program will also reduce damages to agriculture from overbank flooding. Reductions of

peak flood flows are expected to average 44 percent which will reduce damages by at least 44 percent and yield annual benefits of about $13,900.

Roads and bridges

290. Benefits accruing from the road improvement program will be reflected in lower maintenance and bridge replacement costs. Installation of drainage structures designed to prevent erosion and stabilization of cuts and fills will not only reduce road maintenance costs but will also alleviate sediment damages downstream. Reductions in peak flows and sediment rates will enable stabilization of stream channels which will be directly reflected in lessened damages to bridges. Annual benefits from this source will be approximately $38,700.

Railroads

291. No specific program measures have been designed primarily to protect railroad rights-of-way. However, the upstream programs will stabilize channels and reduce peak flows thereby reducing flood damages to railroads. Annual benefits from reduction in flood damages will be about $9,900.

Urban

292. Debris basins and channel rectification work in urban areas augmented by upstream improvements, including revegetation measures, gully plugs, and small detention reservoirs, are expected to be 90 percent effective in controlling future damaging floods in the Fountain Creek area from West Colorado Springs to Green Mountain Falls. Adequate and continuous maintenance of these measures is of primary

importance in this area if continued benefits are to be realized. Annual benefits to urban developments from 90 percent effective control of future damaging floods in the Fountain Creek drainage will be approximately $14,600.

Indirect

293. It is expected that reduction in direct flood water damages for certain types of losses will result in similar proportional reductions in indirect damages. Annual benefits resulting from such reductions are estimated at $22,900.

Sedimentation - Fountain River Watershed

294. Reductions in sedimentation rates will be directly reflected in decreased cleaning costs of irrigation canals and reductions in the rate of sediment deposition in reservoirs. As previously discussed, the average sediment rate of the watershed will be reduced about 58 percent. This will result in an annual reduction in canal cleaning costs of about $4,600. Reservoir storage capacity conserved through reduced sedimentation is valued, on an annual basis, at $2,000.

Sedimentation - Arkansas River

295. Reductions in the amount of sediment carried by Fountain River into the Arkansas River will lessen damages to irrigation systems and the reservoir below the confluence of the two streams. Fountain River contributes an average of 477 acre feet of sediment annually to the Arkansas River which cause damages of $10,400 to John Martin Reservoir and $15,300 to irrigation canals. When the program becomes effective, average annual sediment contributions from the

Fountain River will be reduced 58 percent. Annual benefits from reduced sedimentation damages will be $14,900 of which $8,800 represents reductions in canal cleaning costs and $6,100 the average annual value of benefits to John Martin Reservoir.

Conservation Improvements

Range land

296. In addition to the primary effect of the program as reflected in reduced flood and sediment damage, other beneficial effects will be realized by the land operators. Areas on which conservation measures have been applied show a distinct difference in cover conditions and yields when compared to areas which have been overgrazed and otherwise improperly or inadequately managed. The poorly managed farms show evidences of an unbalanced relation between annual forage produced, period of grazing use, and livestock numbers, and in addition, the ranges are dominated by the least desirable forage species, gullies are numerous and active, and local streams are laden with sediment. Due to more constructive management and the adoption of the other recommended flood control and conservation measures, it is estimated that range forage will increase about 30 percent (10). Although the program reduces woodland grazing in the Black Forest, considerable dry-farm land will be seeded to grass. The over-all increase in forage produced will amount to 19,951 a.u.m. valued at $29,927 annually (table 25). These increased yields will permit adjustments in numbers and season with practically no disturbance of the farm economy.

Table 25. Present and future annual range productivity, Fountain River Watershed, 1947

Type of forage	Present				Future		
	Area	A. per a.u.m.	Forage produced	Forage value	Area	Forage produced	Forage value
	Acres	Number	a.u.m.	Dollars	Acres	a.u.m.	Dollars
Grassland	201,117	3.5	57,462	86,193	201,117	74,701	112,052
Meadow	610	1.3	469	704	610	610	915
Browse	31,477	5.0	6,295	9,442	31,477	8,184	12,276
Woodland	38,839	10.0	3,884	5,826	38,839	-	-
All others	74,442	10.0	7,444	11,166	74,442	9,677	14,515
Hay stubble	10,500	0.5	21,000	31,500	10,500	21,000	31,500
Retired cropland	-	-	-	-	7,000	2,333	3,500
Total			96,554	144,831		116,505	174,758

Cropland

297. With the adoption of the recommended measures, average crop yields will increase. The effects of the program on bottomland areas are reflected in the discussion of flood and sediment reduction benefits. The benefits on the dry land farms will also be substantial. The poorest land will be retired to grass and the best fields will be improved by conservation farming. On isolated farms in and adjacent to the watershed, measures such as recommended in the program not only have held the soil in place but have increased crop production by at least 50 percent (10).

298. Based on a normal distribution of cultivated crops, table 26 gives the yields and values of crops now being produced on 24,053 acres of dry farm land as compared to similar yields and values which are expected to be realized through the adoption of measures on 17,053 acres of the best land in this class. In spite of the reduced acreage under cultivation with the program, yield increases will be great enough to show a net increase in income of $86,033 annually.

Woodland

299. There are 41,579 acres of private timberlands within the watershed in a badly deteriorated condition due to overgrazing, fire, and unregulated cutting. This past treatment has depleted the timber cover to such an extent that full production cannot be expected in less than 100 years. However it is anticipated that intensified fire control, control of grazing, and other improved sustained yield management measures provided for in the program will increase the

estimated present annual growth rate of 25 feet b.m. per acre to about 65 feet b.m. per acre in 100 years. Evaluated on the basis of the current value of logs delivered to the local sawmills of $27 per M feet b.m. the increase in annual increment due to the program will be worth approximately $44,900.

Water loss

300. Increased infiltration rates resulting from installation of program measures will cause an increase in ground water all of which will not reappear within the watershed. The extent of this loss has been estimated and evaluated on the basis of increased net income per acre resulting from irrigation. This loss amounting to $3,130 annually is deductible from total benefits attributable to the program.

Summary of Benefits Evaluated

301. Before the deduction of the amount due to water loss and expected benefits resulting from accomplishments of going programs, total annual benefits amount to $358,100 of which $175,700 results from reduction in floodwater damage, $21,600 from reduction in sediment damage, and $160,800 from conservation benefits. After deducting the amount for water loss and benefits resulting from the accomplishments of going programs, net benefits attributable to the recommended program are $314,400.

Nonevaluated Benefits

302. Over a period of time, the nonevaluated benefits may equal or exceed in importance the evaluated benefits of the flood control program. Although of major importance, it is difficult to definitely evaluate the effects of the program on mitigation of human and social problems created by floods, by soil impoverishment, and by land destruction. The threat of loss of human life will be largely

Table 26. Present and future crop yields and values for dry farm land, Fountain River Watershed, 1947

Crop	Unit	Unit value	Present				Future			
			Acres	Acre yield	Total yield	Total value	Acres	Acre yield	Total yield	Total value
Winter wheat	Bu.	$ 1.99	523	11.5	6,014	$ 11,968	437	17.2	7,516	$ 14,957
Spring wheat	Bu.	1.99	589	7.3	4,300	8,557	491	11.0	5,401	10,748
Barley	Bu.	1.33	720	8.4	6,048	8,044	600	12.6	7,560	10,055
Oats	Bu.	0.80	998	14.4	14,371	11,497	832	21.6	17,971	14,377
Corn	Bu.	1.23	7,311	7.1	51,908	63,847	6,098	10.6	64,639	79,506
Beans	Lb.	0.15	6,215	203.0	1,261,645	189,247	5,184	304.0	1,575,936	236,390
Hay	Ton	17.50	4,089	0.5	1,636	28,630	3,411	0.7	2,388	41,790
Idle	-	-	3,608	-	-	-	-	-	-	-
Total			24,053			$321,790	17,053			$407,823

removed and a greater sense of security will develop. Interruption of irrigation systems by floods is tending to undermine both the economic and social stability of agriculture in the watershed. A reduction in flood hazards will permit more stable planning, provide for increased beneficial use and greater reliability of irrigation water supply, and permit the highest use of land with a minimum of adjustment to the uncertainties created by constant fear of flood losses.

303. Through improvement in infiltration rates of the soil, as much as 300 acre feet of water may be added to the underground supply. The detention dams and water spreading devices will improve the recharge in the aquifers. Development of ground water for irrigation is becoming increasingly important and full development will be dependent upon an augmented water supply. Definite opportunities will be available for the improvement of wildlife and aesthetic values. Tourist and recreational facilities will be protected and enhanced. Table 27 sets forth the amount of annual benefits by types.

PROGRAM APPRAISAL

COSTS

304. To successfully reduce flood and sediment damages on Fountain Creek watershed and attain additional conservation benefits, it will be necessary to install all the interrelated measures comprising the accelerated program and to provide for the continued maintenance of such measures. Total program installation costs amount to $4,020,249 of which $191,561 are maintenance costs during the installation period. Annual costs amount to $144,176 of which $42,569 are

annual maintenance costs after installation. Table 28 sets forth the annual costs allocated to Federal, state and local, and private interests. Detailed program costs by measures appear in table 29. All cost estimates reflect costs of labor, materials, supplies and equipment that prevailed in the watershed in 1947 and insofar as possible were obtained from agencies or groups doing similar types of work.

305. The allocation of costs is based on the relative flood control benefits to be derived from the various measures. The ability of non-Federal interests to contribute to the program, ownership of land, and precedents already established in existing programs. The Federal government will pay the cost of:

1. All measures installed on Federal lands or lands to be acquired.
2. The following measures regardless of ownership of lands on which applied.
   a. Work plans.
   b. Program integration and evaluation.
   c. Acquisition.
   d. Technical services required on cropland, range land, and for installation of special structures.
   e. Purchase of water rights or rights to the use of water.
3. Up to 50 percent of the costs of technical services required on private woodlands.
4. Up to 50 percent of the costs of educational assistance.

Table 27. Estimated annual amount of evaluated program benefits, Fountain River Watershed, 1947

Item	Value (Dollars)	Value (Percent)
Direct flood and sediment reduction		
Agriculture		
Bank cutting	75,700	20.8
Flooding	13,900	3.8
Railroads	9,900	2.7
Roads and bridges	38,700	10.6
Urban	14,600	4.0
Indirect	22,900	6.3
Subtotal	175,700	49.1
Sedimentation		
Canals	13,500	3.7
Reservoirs	8,100	2.3
Subtotal	21,600	6.0
Total direct & indirect benefits	197,300	55.1
Conservation benefits		
Range land production	29,900	8.2
Dry land crop production	86,000	23.6
Timber production	44,900	12.4
Subtotal	160,800	44.9
Grand total all benefits	358,100	100.0
Less costs of water loss	3,100	
Net benefits from original program	355,000	
Less benefits attributable to accomplishments of going programs	40,600	
Net benefits attributable to accelerated program	314,400	

Table 28. Summary of estimated annual costs, Fountain River Watershed, 1947

	Federal	Other public	Private	Total
Annual installation costs	$81,765	$ 4,135	$15,707	$101,607
Annual maintenance after installation	4,881	8,991	28,697	42,569
Total annual costs	$86,646	$13,126	$44,404	$144,176

Table 29. ESTIMATED PROGRAM COSTS IN DOLLARS, FOUNTAIN RIVER WATERSHED

Program measures	Unit	Average unit cost	N. F.	Acquired	Other Federal	Other public	Private	Total	N. F.	Acquired	Other Federal	Other public	Private	Total
	NUMBER OF UNITS								BASE INSTALLATION COST					
Column number	1	2	3	4	5	6	7	8	9	10	11	12	13	14
GROUP 1 - Land Treatment and Related Measures														
Fire protection	Acre						41,579	41,579						
Terracing and reseeding cropland to be retired	Acre	1/ 5.00					5,220	5,220					31,320	31,320
Terraces - cropland	Mile	175.00					260	260					45,500	45,500
Terraces - range land	Mile	50.00				119	1,339	1,458				5,950	66,950	72,900
Tree planting - Federal lands	Acre	40.00	1,970					1,970	78,800					78,800
Tree planting - non-Federal lands	Acre	40.00					1,290	1,290					51,600	51,600
Water spreading and diversion structures	Each	800.00				40	337	377				32,000	269,600	301,600
Road improvements	-	-							37,404			29,728	3,568	70,700
Fencing	Mile	400.00					90	90					36,000	36,000
Purchase of water rights	-	-											2,000	2,000
Technical services and educational assistance														
Cropland	Acre	4/ 7.60					10,000	10,000					76,000	76,000
Range land	Acre	4/ .32					202,000	202,000					64,640	64,640
Woodland (private)	Acre	4/ .40					41,575	41,579					30,663	30,663
Work plans	Acre	4/ .25						583,539						145,885
Land acquisition	Acre	11.17		4,880				4,880		54,510				54,510
Subtotal									116,204	54,510		67,678	677,841	1,062,118
GROUP 2 - Other Measures														
Technical services														179,200
Protection of Manitou Springs and vicinity	-								150,000				540,200	690,200
Flood detention dams	Each	2/ 450.00			269	310	2,224	2,803			121,050	139,500	1,000,800	1,261,350
Stream bank stabilization and revetments	Lin.ft.	3.22			10,488	5,546	52,606	68,640			33,771	17,858	169,391	221,020
Road improvements									87,100			195,526	7,174	289,800
Subtotal									237,100		154,821	352,884	1,717,565	2,641,570
Program Evaluation											80,000			80,000
Program Integration											45,000			3/ 45,000
Subtotal											125,000			125,000
Grand total									353,304	54,510	279,821	420,562	2,395,406	3,828,688

Program measures	N. F.	Other Federal	Other public	Private	Total	N. F.	Acquired	Other Federal	Other Public	Private	Total
	MAINTENANCE DURING INSTALLATION PERIOD					TOTAL INSTALLATION COSTS					
Column number	15	16	17	18	19	20	21	22	23	24	25
GROUP 1 - Land Treatment and Related Measures											
Fire protection				3,744	3,744					3,744	3,744
Terracing and reseeding cropland to be retired				468	468					31,788	31,788
Terraces - cropland				5,850	5,850					51,350	51,350
Terraces - range land			536	6,025	6,561				6,486	72,975	79,461
Tree planting - Federal lands					-	78,800					78,800
Tree planting - non-Federal lands					-					51,600	51,600
Water spreading and diversion structures			2,160	18,198	20,358				34,160	287,798	321,958
Road improvements						37,404			29,728	3,568	70,700
Fencing				8,100	8,100					44,100	44,100
Purchase of water rights				-	-					2,000	2,000
Technical services and educational assistance											
Cropland										76,000	76,000
Range land										64,640	64,640
Woodland (private)				-						30,663	30,663
Work plans				-							145,885
Land acquisition							54,510				54,510
Subtotal			2,696	42,385	59,112	116,204	54,510		70,374	720,226	1,107,199
GROUP 2 - Other Measures											
Technical services										179,200	179,200
Protection of Manitou Springs and vicinity	6,750			24,309	31,059	156,750				564,509	721,259
Flood detention dams		7,263	8,370	60,003	75,636			128,313	147,870	1,060,803	1,336,986
Stream bank stabilization and revetments		6,080	3,213	30,492	39,785			39,851	21,071	199,883	260,805
Road improvements						87,100			195,526	7,174	289,800
Subtotal	6,750	13,343	11,583	114,804	146,480	243,850		168,164	364,467	2,011,569	2,788,050
Program Evaluation								80,000			80,000
Program Integration								45,000			45,000
Subtotal								125,000			125,000
Grand total	6,750	13,343	14,279	157,189	191,561	360,054	54,510	293,164	434,841	2,731,795	4,020,249

Program measures	N. F.	Other Federal	Other public	Private	Total	Federal	Other public	Private	Federal	Other public	Private
	ANNUAL MAINTENANCE COSTS					ALLOCATION OF COSTS: INSTALLATION			ALLOCATION OF COSTS: MAINTENANCE		
Column number	26	27	28	29	30	31	32	33	34	35	36
GROUP 1 - Land Treatment and Related Measures											
Fire protection				832	832	1,872	1,872		416	416	-
Terracing and reseeding cropland to be retired				104	104	12,715		19,073			104
Terraces - cropland				1,300	1,300	20,540		30,810			1,300
Terraces - range land			119	1,339	1,458	31,784	3,892	43,785		119	1,339
Tree planting - Federal lands			-	-	-	78,800					
Tree planting - non-Federal lands				-	-	25,800		25,800			
Water spreading and diversion structures			480	4,044	4,524	289,762	3,416	28,780		480	4,044
Road improvements				-	-	54,052	14,864	1,784			
Fencing				1,800	1,800	17,640		26,460			1,800
Purchase of water rights				-	-	2,000					
Technical services and educational assistance											
Cropland						69,666	5/ 6,334				-
Range land						59,120	5/ 5,520				
Woodland (private)				3,118	3,118	15,332	15,331				
Work plans						145,885					
Land acquisition				-	-	54,510					
Subtotal			599	12,537	13,136	879,478	51,229	176,492	416	1,015	8,587
GROUP 2 - Other Measures											
Technical services						179,200			-	-	-
Protection of Manitou Springs and vicinity	1,500			5,402	6,902	664,808		56,451	1,500	5,402	
Flood detention dams		1,614	1,860	13,334	16,808	1,216,119	14,787	106,080	1,614	1,860	13,334
Stream bank stabilization and revetments		1,351	714	6,776	8,841	185,681	7,164	67,960	1,351	714	6,776
Road improvements					-	188,450	97,763	3,587		-	-
Subtotal	1,500	2,965	2,574	25,512	32,551	2,434,258	119,714	234,075	4,465	7,976	20,110
Program Evaluation		3,000			3,000	80,000					
Program Integration		4,000			4,000	45,000					
Subtotal		7,000			7,000	125,000					
Grand total	1,500	9,965	3,173	38,049	52,687	3,435,736	170,943	410,570	4,881	8,991	28,697

1/ Includes cost of routing excess runoff.
2/ Includes cost of outlet and replacement.
3/ Includes purchase of automobile and office equipment.
4/ Total amount for the 10-year installation period.
5/ Educational assistance.

5. On non-Federal lands the Federal government will contribute:

a. Up to 50 percent of the costs of reforestation, road improvement measures, and fire protection.

b. Up to 90 percent of the cost of the larger diversion structures, flood detention dams, and structural measures for the protection of Manitou.

c. Up to 40 percent of the costs of fencing, terracing, and costs arising from the retirement of cropland.

d. Up to 66 percent of the costs of streambank protection works.

A portion of the cost of applying land treatment measures to privately owned lands may be provided in the form of direct aids. Non-Federal contributions will be required to finance the remaining portions of the above measures.

306. Annual maintenance costs will be provided by the Federal government for all structures and measures on Federal lands and in addition up to one-half the annual maintenance costs for fire protection on private timberlands. If it later becomes necessary the Federal government may participate in the costs of providing technical services and educational assistance to perpetuate the program on non-Federal lands. All other maintenance costs required following installation of the program will be borne by non-Federal interests.

BENEFIT-COST RATIOS

307. Prior to this section of the appendix all benefit and cost estimates have reflected prices that prevailed in the watershed during 1947. In order to reflect anticipated future average prices, in this section, benefits and costs are adjusted by use of price indexes suggested by the Bureau of Agricultural Economics. The suggested price indexes estimated to reflect future average prices are: prices paid by farmers 165, prices received by farmers 150, and cost of construction 325. Corresponding price indexes in 1947 were 231, 278, and 413, respectively. The base period for farm prices is 1910-14 = 100, and for construction costs 1913 = 100. The percentage change between 1947 indexes and expected future indexes were determined and applied to benefits and costs to adjust them to the anticipated future average price level. In converting total installation costs an interest rate of 2.5 percent was used

for costs allocated to Federal, state, and local governments and 4 percent for such costs allocated to private interests.

308. A summary of anticipated future average benefits and costs and an analysis of the over-all benefit-cost ratios is presented in table 30. The ratio is favorable for installation of the program since benefits evaluated exceed total costs by a ratio of 1.70:1.

Table 30. Summary of estimated annual benefits and program costs, Fountain River Watershed

	Federal	Other public	Private	Total
Annual installation costs	$64,100	$ 4,646	$ 9,800	$ 78,546
Annual maintenance after installation	3,856	7,093	22,308	33,257
Total annual costs	$67,956	$11,739	$32,108	$111,803
Total annual benefits				$189,745
Ratio of benefits to costs				1.70:1

Program Analysis by Group or Individual Measures

309. An analysis was made to determine economic feasibility of each of the two groups of related measures and also by individual Group 2 measures.

310. Average annual costs for Group 1 measures are about $30,283 with estimated benefits of $95,570 resulting in a ratio of benefits in excess of costs of 3.07:1.

311. For Group 2 measures the over-all benefits exceed the costs by a ratio of 1.19:1. For individual measures within the group the ratio of benefits to costs is as follows: Values involved are set forth in tables 31 and 32.

Measure	Benefit-Cost Ratio
Protection of Manitou Springs and vicinity	.93:1
Flood detention dams	1.02:1
Streambank stabilization	1.53:1
Road improvement	2.47:1

312. Installation of all Group 2 measures will produce a favorable cost-benefit ratio with the exception of the improvement works to protect Manitou Springs and vicinity. These improvement works are designed to protect a town with a normal population in 1940 of 1,462 which has been steadily increasing and which may be doubled during the summer months with the influx of vacationists. The town is situated in a narrow canyon of Fountain Creek at the confluence of Williams Canyon, Ruxton Creek, and Black Canyon. The drainage areas above the town consists of steep slopes, much exposed bare rock or denuded areas which are conducive to rapid runoff and high peak flows which debouch from the steep canyons into the highly developed urban areas. Since about 1900, damages to the extent of $729,000 have occurred and in addition three lives have been lost. Only by fortunate circumstances has this loss of life been low in past floods, for the probability of much greater losses has been constantly present during major floods. Future losses will be

Table 31. Estimated annual benefits, costs, and benefit-cost ratios of Group 1 and Group 2 program measures, Fountain River Watershed

	Group 1			Group 2			Program total
	Instal-lation	Mainte-nance	Total	Instal-lation	Mainte-nance	Total	
Program costs							
Federal	$17,080	$ 329	$17,409	$47,020	$ 3,528	$50,548	$ 67,957
Other public	957	792	1,749	3,689	6,301	9,990	11,739
Private	4,704	6,421	11,125	5,096	15,887	20,983	32,108
Total	$22,741	$ 7,542	$30,283	$55,805	$25,715	$81,521	$111,804
	From Group 1 Measures			From Group 2 Measures			
Program benefits							
Flood reductions	$14,489			$88,324			$102,813
Sediment reductions	6,571			7,659			14,230
Cropland conservation	39,164						39,164
Range land conservation	12,873			891			13,764
Woodland conservation	21,199						21,199
Total	$94,296			$96,874			$191,170
Less water costs	$ 1,425						$ 1,425
Net benefits	$92,871			$96,874			$189,745
Ratio benefits to costs	3.07:1			1.19:1			1.70:1

Table 32. Estimated annual benefits, costs, and benefit-cost ratios of individual Group 2 measures, Fountain River Watershed

Program Measure	Costs	Benefits	Benefit-cost ratio
Protection of Manitou Springs and vicinity	$23,792	$18,238	.93:1
Detention dams	43,245	44,344	1.02:1
Streambank stabilization and revetments	12,865	19,736	1.53:1
Road Improvements	5,896	14,556	2.47:1
Total	$81,521	$96,874	1.19:1

greater with a probable increase in loss of life unless remedial works are installed to protect the increasing population and development much of which is already encroaching further upon the flood plain and within the narrow confines of Williams and Black Canyons. Numerous attempts have been made by local interests to reduce the hazard that exists. However, the cost of the treatment required to provide reasonable protection is beyond that which local interests can bear.

313. In view of the serious hazard that exists and the inability of local interests to provide adequate protection, the installation of these protective works is recommended even though the tangible benefits do not equal the costs.

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REVIEW AND COMMENTS BY OTHER AGENCIES

In compliance with adopted policies by the Federal Inter-Agency River Basin Committee preliminary drafts of the report and appendices were sent to those agencies for review and comments.

Comments received from the agencies concerned were given careful consideration in preparation of the final draft.

Copies of letters containing comments by the various agencies follow:

Letter from Fish & Wildlife Service, dated January 10, 1949.

Letter from Corps of Engineers, dated January 26, 1949.

Letter from Bureau of Reclamation dated February 3, 1949.

Letter from Federal Power Commission dated February 23, 1949.

Letter from U. S. Geological Survey dated March 24, 1949.

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UNITED STATES
DEPARTMENT OF THE INTERIOR
FISH AND WILDLIFE SERVICE
Office of the Regional Director
Albuquerque, New Mexico
P. O. Box 1306

R2-RBS

January 10, 1949

Mr. Reed W. Bailey, Director
Intermountain Forest & Range Experiment Station
U. S. Forest Service
Ogden, Utah

Dear Mr. Bailey:

Reference is made to your letter dated December 28, 1948, your file RIFC-INT, which transmitted for our review and comments a preliminary draft of your Survey Report, Fountain River Watershed, Colorado, dated April 1, 1948.

A review of your report reveals that your plan for runoff and waterflow retardation and soil erosion prevention for flood control purposes in the watershed would provide for the following measures:

(1) Reseeding of about 7,000 acres of privately-owned land,
(2) Construction of 1,820 miles of terraces and terrace dikes,
(3) Reforestation of about 3,500 acres,
(4) Construction of three debris dams,
(5) Improvement of about 17,450 feet of channels,
(6) Construction of about 4,400 small flood detention dams,
(7) Construction of about 500 water spreaders and diversion structures,
(8) Stabilization of about 30,000 linear feet of stream banks, and
(9) Miscellaneous interrelated measures.

The proposed program would not affect any existing Fish and Wildlife Service activity in the Fountain River Watershed. The program should result in over-all benefits to wildlife resources in the area. However, such benefits as would accrue could probably be materially increased if the program, in its work stages, should be developed with the secondary purpose in mind of benefiting wildlife. This Service would be happy to cooperate with your office in that undertaking.

Your consideration in soliciting the views and opinions of this office on your report is sincerely appreciated. The draft copy of the report is returned herewith.

Very truly yours,

/s/ K. C. Kartchner

K. C. KARTCHNER
Acting Regional Director

Incl.-Draft of report

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DEPARTMENT OF THE ARMY
CORPS OF ENGINEERS
Office of the District Engineer
Albuquerque District
P. O. Box 1538
Albuquerque, New Mexico

26 January 1949

Subject: Review of Preliminary Draft of the Department of Agriculture Flood Control Survey Report on the Fountain River (Colorado) Watershed

To: Mr. Reed W. Bailey, Director
Intermountain Forest and Range Experiment Station
Forest Service
Department of Agriculture
Forest Service Building
Ogden, Utah

Dear Mr. Bailey:

Reference is made to your letter dated 28 December 1948, file RIFC-INT, Fountain River Watershed Survey Report, requesting an informal review of the subject report and appendix by this office.

Your report on a survey of Fountain Qui Bouille (Fountain) River watershed has been reviewed with considerable interest inasmuch as this office is currently preparing a review survey report on Arkansas River and Tributaries above the mouth of Walnut Creek, Kansas. Since Fountain River is tributary to the Arkansas it is included in these studies, and your report will be very useful for reference.

It was noted in your letter that the report and appendix material is still in preliminary form and not subject to public release.

With reference to the review of the report the following comments are made regarding the subject matter in the Report and Appendix dated April 1, 1948:

a. Report, page 15, line 9.

"The major project is a concrete channel---"

Comment. Records in this office indicate that the Monument-Fountain channel through the City of Colorado Springs is paved with grouted riprap instead of concrete.

b. Report, page 15, line 19.

"This has now been authorized and a definite project report has been prepared."

Comment. It is suggested that a line be added immediately after the above quotation stating that construction of the floodway was commenced in September 1948.

c. Appendix, page 15, paragraph 42, line 4.

"The evaluation of the damages were based on the productive value of water in case of depletion of the conservation pool and upon the anticipated flood reduction benefits in the case of flood control storage."

Comment. It is noted in paragraph 241 of the Appendix that the average annual damages resulting from 75 acre-feet of Fountain River sediment being deposited in the flood control and irrigation pool amount to $21,200 in John Martin Dam. The remedial measures proposed would reduce these damages by an estimated 58 per cent, making the estimated annual value of benefits $12,296. This evaluation appears high when compared to an evaluation based on 1947 replacement costs estimated to be approximately $50 per acre-foot for 14,000 acre-feet of storage on the Fountain River Watershed, as stated in paragraph 240, page 98 of the Appendix. In this connection attention is invited to paragraph 41 of Appendix, line 21, which states in part "An evaluation based on the wealth created by a reservoir would give a much higher damage figure---. Use of a replacement value results in a very conservative estimate." It is concluded that methods used in calculating sedimentation damages to reservoirs are inconsistent and that justification should be shown for the use of productive value of water at John Martin Dam over a 100-year period in an arithmetical progression to arrive at the average annual value of damages.

d. Appendix, page 124, paragraph 296.

"Through improvement in infiltration rates of the soil, as much as 300 acre-feet of water may be added to the underground water supply."

Comment. It is believed that additional information should be included to show the effect of the remedial program on water yields. Specifically this should include (a) estimated reduction in volume of flood runoff in acre-feet, (b) availability of ground water recharge for pump irrigation or as inflow to Fountain River, and (c) the apparent net effect of the program on irrigation water supplies in acre-feet. If irrigation water supply at John Martin Dam is reduced, is it not a detriment that should be evaluated and deducted

from benefits shown, using methods based on productive value of water as used in evaluating sedimentation damage?

Sincerely yours,

/s/ Joseph O. Killian

JOSEPH O. KILLIAN
Lt Col, CE
District Engineer

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Attention: 7-740

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
Regional Office, Region 7
318 New Customhouse
Denver 2, Colorado

February 3, 1949

Mr. Reed W. Bailey
Director, Forest Service
U. S. Department of Agriculture
Forest Service Building
Ogden, Utah

Dear Mr. Bailey:

Thank you for your letter of December 28, 1948, transmitting a copy of the preliminary draft of the Department of Agriculture flood control survey report on the Fountain River Watershed.

In the limited time available for review of the report, the analysis presented appears to be comprehensive and appropriate. We feel that the Forest Service is to be commended for the presentation made. Flood hydrologic studies of the Fountain River Basin are adequate and benefit data are presented in accordance with acceptable methods and standards.

The construction of more than 4,000 retention dams called for in the report doubtless would cause some water loss by evaporation which, together with other means of retarding runoff, would diminish water available for irrigation in the Arkansas River Basin. In this connection, we suggest that the provisions of the Arkansas River Compact now being considered by the legislatures in both Colorado and Kansas be analyzed to ascertain whether there would be any conflict between the compact and the program proposed for runoff and water flow retardation and soil erosion prevention for flood control purposes contained in the report.

Very truly yours,

/s/ W. E. Blomgren

W. E. Blomgren,
Assistant Director

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FEDERAL POWER COMMISSION
Regional Office
412 Neil P. Anderson Building
Fort Worth 2, Texas

Attention: 7-740 February 23, 1949

The Director
Intermountain Forest and Range Experiment Station
U. S. Forest Service
Ogden, Utah

Subject: RIFC-INT, Fountain River Watershed Survey
Report Arkansas River Basin, Colorado

Dear Sir:

In accordance with the request made by your memorandum of February 7, this office has briefly reviewed the preliminary draft of the subject report and appendix. Our comments follow.

The Forest Service, U. S. Department of Agriculture, has completed a watershed survey of the Fountaine Qui Bouille (Fountain) River Watershed, Colorado, and prepared the subject report under authority of the Flood Control Act of 1936, as amended by the Flood Control Act of 1937 (Public Law 406, 75th Congress).

The Forest Service has investigated the flood and erosion problems existing in the 927 square mile watershed of the Fountain River in Colorado. The investigating agency finds that excessive surface runoff and accelerated erosion from the upland areas have produced floods causing excessive damage to bottomland values within the watershed, and in the Arkansas River Valley below the confluence of the two rivers. Damages from such floods are estimated at $278,700 annually. A watershed restoration and management program is recommended to reduce these damages. This program contemplates a number of soil conservation and flood control measures, including for the plains region about 4,400 flood detention dams on the basis of one to ten dams per square mile, with storage capacities totalling up to 20 acre-feet per square mile. Each reservoir would have an outlet through the earth-fill dam and would retain about 5 percent of the capacity of dead storage.

The proposed program would require about 10 years for development, at an estimated cost of $4,318,700 to the Federal Government, and of $991,800 to local interests, based on 1947 prices. Annual benefits are expected to total $288,000, including $12,296 from reduced sedimentation of John Martin Reservoir downstream on the Arkansas River. The Forest Service estimates that the over-all ratio of benefits-to-costs is 1.33 to 1.

This office has not made a detailed review of the report. Nevertheless, it appears that the flood control improvements recommended in your program may prove beneficial to existing and future flood control development downstream on the Fountain and Arkansas Rivers in reducing both flood stages and the present rate of storage depletion from sedimentation.

The report does not discuss any effect the recommended program may have on possible future downstream hydroelectric power development. However, so far as is known, future water power development is not being considered by any Federal agency for the Fountain River in the Colorado Springs to Pueblo reach, or for the Arkansas River below Pueblo in the State of Colorado.

The report states that irrigation is the most important agricultural use of water in the Fountain River Watershed, and also that from 5,000 to 6,000 acres along the Arkansas River between Pueblo and John Martin Reservoir are dependent on Fountain River water. It is understood that the runoff of the Fountain River Watershed has been overadjudicated.

From the above it is evident that any use of water for a possible future water power development in the area would be subservient to irrigation requirements and could operate only in the irrigation season unless a downstream storage unit were provided for reregulation.

Your investigations may have determined that an effect of the recommended development would be to increase the base flow of the Fountain River by converting a portion of surface flood runoff to delayed inflow in the form of seepage to the river channel. Any augmentation of stream flow during dry periods should prove beneficial to irrigation and power development. On the other hand, such possible improvement in the present regimen of the Fountain River and tributaries may be more than nullified by the losses to present conditions runoff which will occur from increased transpiration, evaporation, deep percolation and consumptive use because of the revegetation and terracing measures, and the dead storage in the 4,400 proposed flood detention reservoirs under the proposed development.

However, cognizance of the contingency discussed in the foregoing is indicated, to some extent, in paragraph 269 of the report appendix which states:

"Provision will be made for the purchase of water rights which may be required as the result of the installation of any recommended measure. Purchase will be in accordance with state water laws."

In conclusion, it appears that your proposed program for improvement of the Fountain River Watershed may cumulatively affect existing and future downstream irrigation and possible hydroelectric power development. The magnitude of such effect and whether favorable or unfavorable can be ascertained only by lengthy and detailed investigation, which is considered beyond the scope of this review.

The foregoing comments are submitted at field level without prior approval by higher authority, and, therefore, are not to be considered the official opinion of the Federal Power Commission.

This opportunity for cooperative examination of the development possibilities of the Fountain River Watershed in connection with the subject report is appreciated.

In accordance with your request, we are returning the report and appendix.

Very truly yours,

/s/ Wilber F. Fairlamb

Wilbur F. Fairlamb
Regional Engineer

Enclosure No. 26647:
2 volumes as noted

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UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
302 West 15th St.
Austin 14, Texas

March 24, 1949

Mr. Reed W. Bailey, Director
U. S. Forest Service
Forest Service Building
Ogden, Utah

RIFC-INT
FOUNTAIN RIVER WATERSHED - Survey report

Dear Mr. Bailey:

The captioned report, dated April 1, 1948, has been reviewed by officials of the U. S. Geological Survey in connection with "Distribution and coordination of reports, Federal Inter-Agency River Basin Committee."

Appropriate comments relating to this proposed project are contained in the attached report prepared by Mr. F. M. Bell, District Engineer, U. S. Geological Survey, Denver, Colorado.

Very truly yours,

/s/ Trigg Twichell

Trigg Twichell
Geological Survey
Contact Official

GEOLOGICAL SURVEY'S REVIEW OF SURVEY REPORT
Runoff and waterflow retardation and soil erosion prevention for flood control purposes.
FOUNTAINE QUI BOUILLE (FOUNTAIN) RIVER WATERSHED
COLORADO
by U. S. Forest Service, Ogden, Utah, April 1, 1948

This report proposes the expenditure of $5,310,500 over a 10-year period for reduction of flood and sediment damage in the Fountain River watershed in Colorado. The principal features of the proposed program consist of vegetative and related measures at a cost of $331,300, channel and structural works costing $3,970,700, and aids and supplements costing $1,008,500. The latter item includes $856,800, or 16 percent of the total cost, for such features as engineering supervision, technical assistance, work plans, program evaluation, and program coordination. It is further noted that local interests will be expected to furnish $991,800 of the total cost and $60,700 of the $109,700 annual operation costs. The remaining $4,318,700 of capital cost and $49,000 annual operation costs are to be contributed by the Federal government.

The benefits assigned to the program include reduction of flood threat to human life, reduction of peak discharge of 10, 25, and 30 year floods of 37 percent, substantial reduction of sediment originating from both surface erosion and bank cutting, substantial reduction of road and bridge damage, increase in ground water recharge, and increase in forage production from cropland, woodland, and range. Cost versus benefit analysis indicates the over-all ratio of benefits to cost is 1.33 to 1.

In reviewing reports of other agencies the Geological Survey feels that its comments should be limited to its particular fields of activity. Accordingly, although it appears that the report contains many statements, claims, and conclusions not too well supported by basic data, the following comments relate entirely to the hydrologic aspects of the report.

Among the nonevaluated benefits of the proposed program is an increase of as much as 300 acre-feet annually in the underground water supply of the basin. Neither the report nor the appendix contain basic data in support of this statement and since there has been no extensive quantitative study of the ground water resources of the area, it must be concluded that the statement is subject to question.

Since increase in ground water supply is a benefit that can be readily evaluated, particularly in an area where surface water supplies during the irrigation season are limited and overappropriated, it seems unfortunate that this phase of water conservation did not receive more attention. It is conceivable that a comprehensive ground water study might have resulted in findings that would have justified a definite program of ground water recharge having a higher benefit-cost ratio than some of the proposals recommended.

A striking feature of the report is the lack of basic hydrologic data in the form of streamflow records, actual flood hydrographs, and flood frequency curves. Although gaging station records at Fountain and Pueblo were used in the study, the record on Monument Creek at Pikeview equal in length to that at Fountain apparently was not used. Lack of streamflow data is admitted in the report, but it seems unfortunate that the assistance of the Geological Survey in establishing additional gaging stations in the watershed was not requested when the survey report was authorized in 1937. Had there been a network of gaging stations in operation since 1937 at strategic locations in the basin, much additional streamflow data would have been available. Additional streamflow data would have provided a basis not only for checking synthetic hydrographs and judging conclusions but also for investigating other important aspects of flood control not mentioned in the report.

In Colorado an important phase of any program that changes the natural regimen of a stream is its effect on water rights. Beyond a provision of $2,000 for purchase of water rights, the report neglects this important point almost entirely. This despite the fact that the maximum proposed flood reductions take place during floods that occur at frequent intervals. Substantial reduction of such floods could seriously affect water users having only high water storage rights and also might retard natural runoff to the benefit of certain water rights and to the detriment of others. It is not unlikely that local interests would decline to support the project until it was proved that water rights would not be adversely affected.

Flood frequency data is admittedly meagre because of lack of data. However, clarification of that presented may be desirable. It is noted that Table 22 in the Appendix indicates the 50-year flood as 11,400 c.f.s. yet historical treatment lists 6 floods in excess of 40,000 c.f.s. during an 85-year period.

It is believed the effectiveness of the report could be improved by photographs, flood hydrographs both actual and computed, and other illustrative material. Such material might provide additional support for the statement that the program will reduce 10, 25, and 50 year floods by exactly 37 percent. It is further believed that the report should indicate in considerable detail the effect of the proposed program on the waters of the Arkansas River since the Arkansas River Compact provides that future works for the utilization and control of waters of that stream "shall not be materially depleted in usable quantity or availability for use."

The Geological Survey concurs in the general conclusion that the control measures recommended will reduce flood and sediment damage originating from excessive runoff and erosion and will increase agricultural production of the area but believes the detailed benefits claimed are not in all cases well supported by hydrologic facts. The

Survey feels that additional investigation is desirable which should include the establishment and operation of a network of gaging stations at strategic points, quantitative ground water studies, flood routing studies, studies of evaporation and transpiration losses and studies of the effect of the project on water rights and the Arkansas River Compact.

F. M. Bell, District Engineer
U. S. Geological Survey
Water Resources Division, SWB.
Denver, Colorado

March 15, 1949